



Nuclear Energy Safety Symposium

Proceedings Report



*Applying scientific thinking
in the service of society*

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Nuclear Energy Safety Symposium Proceedings Report

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The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996 in the presence of then President Nelson Mandela, the Patron of the launch of the Academy. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science for the benefit of society, with a mandate encompassing all fields of scientific enquiry in a seamless way, and including in its ranks the full diversity of South Africa's distinguished scientists.

The Parliament of South Africa passed the Academy of Science of South Africa Act (*Act 67 of 2001*), as amended, which came into operation on 15 May 2002. This has made ASSAf the official Academy of Science of South Africa, recognised by government and representing South Africa in the international community of science academies.



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List of Prefixes

| Prefix | Symbol | Power |
|--------|--------|------------------|
| milli | m | 10 ⁻³ |
| Kilo | k | 10 ³ |
| Mega | M | 10 ⁶ |
| Giga | G | 10 ⁹ |
| Tera | T | 10 ¹² |

List of Units

| Unit | Symbol | Definition |
|------------------|-----------------|--|
| Becquerel | Bq | International System of Units (SI) derived unit of radioactivity |
| Cubic centimeter | cm ³ | SI unit of volume |
| Curie | Ci | A non-SI unit of radioactivity |
| Sievert | Sv | Equivalent dose of radiation |
| Watt | W | SI unit for power |

List Chemical Elements

| Element | Symbol |
|-----------|--------|
| Helium | He |
| Plutonium | Pu |
| Uranium | U |

List of Acronyms/Abbreviations

| | |
|---------|---|
| AC | Alternating current |
| ASSAf | Academy of Science of South Africa |
| BWR | Boiling water reactor |
| DST | Department of Science and Technology |
| HPIC | High pressure coolant injection |
| EURATOM | European Atomic Energy Community |
| IAEA | International Atomic Energy Agency |
| IC | Isolation condenser |
| ICRP | International Commission on Radiological Protection |
| INCOSE | International Council of Systems Engineering |
| IRP | Integrated Resource Plan |
| Necsa | South African Nuclear Energy Corporation |
| NEI | Nuclear Energy Institute |
| NES | Nuclear Energy Safety |
| NGOs | Non-governmental organisations |
| NIASA | Nuclear Industry Association of South Africa |
| NNR | National Nuclear Regulator |
| NNSA | National Nuclear Security Administration |
| NRB | National Regulatory Body |
| NSS | Nuclear Safety Standards |
| PUI | Peaceful Uses Initiative |
| PWR | Pressurised water reactor |
| R&D | Research and Development |
| RCIC | Reactor Core Isolation Cooling |
| RHR | Residual Heat Removal |
| SCA | Safety Case Analysis |
| SE | Systems engineering |
| SRS | Stakeholder requirement specification |
| TEPCO | Tokyo Electric Power Company |
| UK | United Kingdom |
| URS | User requirement specification |
| US | United States |
| WANO | World Association of Nuclear Operators |
| WINS | World Institute of Nuclear Security |
| WNA | World Nuclear Association |

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Welcome and Purpose

Prof Robin Crewe,
President, Academy of Science
of South Africa



Prof Crewe welcomed the participants and representatives of the media to the symposium. He introduced the speakers, the chairpersons of the sessions and important guests including several international participants. He welcomed Mr Toshiro Ozawa the Ambassador of Japan, Mr Tshinyadzo Mphephu of the Parliamentary Portfolio Committee on Energy, and Mr Charles Randolph of the US Embassy. He apologised on behalf of the Minister of Energy, Ms Dipuo Peters and indicated that **the programme would be modified to allow for extended discussions.**

The topic for the 2011 annual symposium arose from a discussion between ASSAf and the Deputy Minister of Science and Technology (DST) towards the end of 2010. ASSAf had been requested to prepare a commentary on the Integrated Resource Plan (IRP) 2010. ASSAf presented the commentary to the DST early in 2011. Copies of the commentary were available to participants. Subsequently, Prof Crewe had attended the G8+5 Academies of Science meeting in Paris, where the idea of holding a symposium on nuclear energy safety in South Africa was initiated. It was deemed desirable to invite a number of international guests to participate in the symposium in order to get an international view of the issues raised in relation to nuclear energy safety. A representative of the Royal Society (UK), who was also present at the meeting in Paris, indicated that the Royal Society was due to complete a report on nuclear energy that would be released around the time that the symposium

would be held in South Africa. Discussions regarding the symposium continued at an InterAcademy Council meeting in Washington DC where an analysis of the events that had taken place at Fukushima in Japan was presented. Representatives of the Science Council of Japan indicated that they would be prepared to send a representative to present at this symposium.

The idea of the symposium had been endorsed by the ASSAf Council. The ASSAf staff had organised the event and were commended for having mobilised international partners, as well as a variety of South African stakeholders to participate in this exchange of ideas. It was coincidental that the Royal Society's report was due to be released in London on the same day as the symposium. Prof Roger Cashmore had agreed to participate via a video link in order to present a brief overview of the report to participants at the symposium.



Disarmament and Global Threat Reduction in the Context of a Growing Nuclear Power Industry

Ms Anne M Harrington,

Deputy Administrator for Defence Nuclear Non-proliferation, National Nuclear Security Administration, US Department of Energy

Prospects for Nuclear Energy

Current forecasts suggest that the world will see an increase in global energy consumption of over 50 per cent by 2030. Of this growth in demand, 70 per cent is expected to come from developing countries.

The March 2011 events at the Fukushima Daiichi nuclear power plant have necessitated a review of nuclear power plant safety and operations. Many countries have already signalled their intention to proceed with plans to engage with a nuclear future. There are many reasons for this: nuclear power can play a significant and expanding global role in promoting economic growth, reducing carbon pollution, and satisfying the world's increasing demand for base load electricity.

Globally, nuclear energy is undergoing renewed growth with 65 new reactors under construction in 15 countries. In the United States (US), a renewed interest in nuclear energy has resulted in blueprints for the first new nuclear power plants in over 30 years. Licence applications have been submitted to construct 26 new nuclear reactors in the US.

In the US, nuclear energy provides about 20 per cent of total electricity, but 70 per cent of the country's carbon-free electricity. In addition, nuclear power plants do not release air pollutants, providing an important option for improving air quality. Globally, nuclear power plants supply 14 per cent of the world's electricity. Fifteen countries rely on nuclear energy to supply at least a quarter of their total electricity. Nuclear power plants are flexible and very reliable. In the US, nuclear power is regarded as an essential element of the 21st century energy mix, together with renewable energy sources.

It is difficult to have any conversation on nuclear energy without referring to the events of March 2011 in Japan. The risks associated with nuclear power are now better appreciated and have given rise to a healthy global debate. The lessons learned from the Fukushima disaster present opportunities for numerous studies and the involvement of academic organisations such as science academies. For example, the roles and integration of multiple systems is an issue that merits serious exploration. Safety features are an integral part of a power plant's design.

Typically, once a plant is built, the security, safeguards and emergency response elements are layered on top of the basic design. The lack of systems integration creates a situation where key emergency response organisations in the community do not have a full understanding of one another's functions or of how the various systems interact. This is a great challenge that requires industry, regulatory bodies, non-proliferation experts and others to develop a habit of cooperation and communication from project inception to operation.

Safeguarding Nuclear Material

In addition to natural events that can cause problems at nuclear power plants, it is also necessary to consider the potential theft or diversion of nuclear material. Since the 2010 Nuclear Security Summit, in which 46 nations, as well as the European Union (EU), participated, considerable progress has been made in securing the world's most vulnerable nuclear materials, plutonium and highly enriched uranium. South Africa has helped lead the way in this effort.

Increased commerce in nuclear materials is anticipated as a result of the expansion of nuclear energy generation. As a growing number of power plants require fuel, uranium will have to be enriched and fabricated into fuel that may have to be transported some distance to reach power plants. Used fuel must either be stored securely in the country in which it was used, or it may be shipped back to the country of origin. Some countries may choose to reprocess used fuel, introducing another set of complications. An increased demand for uranium

and its increased value as a commodity could raise interest in trafficking in raw materials, necessitating more attention to mine security and a better understanding of how to 'fingerprint' the sources of uranium. The nuclear renaissance could begin to pose a new series of challenges, particularly in relation to security. These issues will have to be addressed before new nuclear power plants are designed and constructed.

The IAEA Peaceful Uses Initiative (PUI)

One of the most appropriate means of dealing with some of the challenges is through the central role of the International Atomic Energy Agency (IAEA). The PUI provides technical support to countries that are planning to develop nuclear energy. It concerns itself with the creation of the infrastructure needed to support safe and secure custodianship of nuclear technology and with the development of other areas of nuclear technology, such as its application to health, agriculture and hydrology. It was evident in the bilateral discussion at the recent IAEA General Conference that the PUI has become very popular and, to date, has benefited over 100 member states. One of its most important aspects is that it allows countries, particularly first-time entrants into the nuclear industry, to begin planning the development of their nuclear power infrastructure. South Africa has a role to play in this regard, as a regional leader in Africa.

The International Framework for Nuclear Energy Cooperation provides a venue for countries to converse about and address non-proliferation issues. It also seeks to explore mutually beneficial approaches to

ensure that the peaceful use of nuclear energy proceeds in an efficient manner, meeting the highest standards of safety, security and non-proliferation. Such conversations are an important part of the nuclear renaissance and an important way of ensuring the safety and security of the renaissance.

The National Nuclear Security Administration (NNSA), as well as other parts of the US Department of Energy, work together with other US government and international partners, such as the Nuclear Regulatory Commission and the IAEA, to help countries develop the nuclear infrastructure necessary for the safe and secure expansion of nuclear energy. Through an extensive network of laboratories and universities, NNSA facilitates technical engagement projects with countries at all stages of nuclear development.

Africa will also have newcomers to nuclear energy. As a country with advanced nuclear technology and the associated expertise, South Africa can play a crucial role in the continent's secure nuclear future. It is also expected that the planned expansion of the G8 Global Partnership will allow many more countries to participate in this process. This mechanism may prove to be very useful in the development of cooperation and collaboration in relation to nuclear and radiological security.

Infrastructure development and capacity building are major elements that will help address the security issue. They are supported and affirmed by:

- The IAEA Milestones document which aims to help member states under-

stand the commitments and obligations associated with a nuclear power programme.

- The 2010 Nuclear Security Summit.

NNSA is engaging with 17 bilateral and regional partners on 94 different projects to improve capabilities for nuclear materials control and accounting.

South Africa

South Africa can play an important leadership role in many areas in the region. NNSA is very proud of the effort carried out with South Africa to convert its research reactor for the production of medical isotopes from highly enriched uranium to low-enriched uranium. Together we demonstrated that it is possible to convert reactors without affecting the technical capacity or losing the commercial production of the reactor. An important contribution to this effort was a study by the US National Academy of Sciences on the conversion of reactors, particularly for the production of molybdenum-99 medical isotopes. Based on the study, NNSA launched discussions with a number of countries. To date, the greatest progress has been made with South Africa, which now leads the way globally in demonstrating the technical and commercial feasibility of such a conversion. This is an important example of how countries can work together to address security issues by limiting the use of highly enriched uranium while supporting the commercial activities of the nation.

The nuclear renaissance environment presents some unique opportunities. This

is the beginning of a long process that will require a great deal of collaboration and interaction. In terms of uranium becoming an important asset in the future, one of the ways to keep track of assets is through the emerging field of nuclear forensics involving material characterisation and analysis. As uranium increasingly becomes a traded commodity, it will be useful to track it at its elemental level and to be able to identify its origin. NNSA is undertaking a project with the IAEA which involves the development of security guidelines for uranium mining and the development of basic forensic capabilities in countries around the world. There is the possibility of a global network of laboratories that have fundamental capabilities in uranium characterisation and the development of databases to identify the sources of

uranium. With the IAEA taking a lead role in this area, South Africa, which is fortunate to have an organisation like the South African Nuclear Energy Corporation (Necsa), is poised to become a regional leader in the emerging field of nuclear forensics.

In conclusion, the potential impact of the expansion of nuclear energy on disarmament and threat reduction efforts should not be ignored. Action to mitigate the potential impact should be taken now, before uranium is mined and power plants are constructed. Working with the IAEA and in partnerships with other countries, a substantial contribution can be made to promoting peaceful uses of nuclear technology while minimising related risks.



Nuclear Energy – Understanding Project-related Risks

Mr Phumzile Tshelane,

Vice-President, Nuclear Industry Association of South Africa (NIASA)

Introduction

Global nuclear electricity production has increased steadily since the early 1970s and has remained at around 2 500 Twh over the past few years (Figure 2.1). The nuclear share of total world electricity production increased sharply in the 1970s and 1980s, dropping off slightly to about 14 per cent in 2009.

South African energy demand has also followed international trends, and with the commitment to reduce the carbon footprint, it is clear that South Africa will have to use nuclear energy to produce electricity; however, there are some challenges in terms of deploying nuclear technology to produce the projected 9.6 GW of electricity for South Africa. These challenges are the focus of this presentation.

The South African government approved the Integrated Resource Plan (IRP) 2010, which provides for the production of 9.6 GW of electricity from nuclear energy by 2030. The IRP envisages that the first nuclear plant will be commissioned in 2023. This is an ambitious, yet achievable, target that demonstrates South Africa's willingness and determination to develop clean energy, including nuclear power, and also displays trust in nuclear technology.

There is renewed global interest in nuclear energy and the key drivers are:

- its contribution to the country's energy security of supply;
- improved nuclear economics in terms of operation;
- environmental advantages, particularly low carbon emissions;
- a very good safety record since the Chernobyl disaster, with the Fukushima accident demonstrating the high level of safety, as the disaster was largely outside the nuclear power plant.

Project Risks

The key risks in undertaking a nuclear new build project relate to regulatory, finance issues, the localisation of manufacture, the project schedule, availability of skills in a variety of technical fields and public acceptance. These risks can manifest positively or negatively, as some of the risks can present real opportunities.

The key elements of a nuclear new build project are the following: site characterisation, plant procurement and contracting, licensing, technology and design, financing and execution. Effective planning around these elements will result in the successful deployment of the nuclear power plants. Experience has

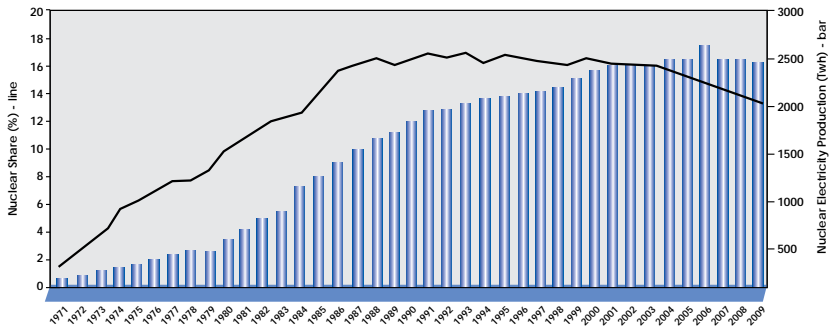


Figure 2.1: Nuclear electricity production (bars) and nuclear share (per cent) of total world electricity production (line)¹

shown that disruptions related to time, work schedule and projected cost overruns are common in large power projects. Risks therefore must be identified and the necessary mitigation measures must be built into the planning. Site characterisation risks should be continuously appraised and reviewed frequently to ensure effective management.

The national regulatory framework has to support the nuclear power environment and should be well understood in order to minimise risks. It is important to secure qualified nuclear sites and avoid encroaching of housing developments around those identified nuclear sites. A legitimate stakeholder engagement process must be undertaken to ensure that the public is well informed about the nuclear power project.

The type of contracts will affect the costs and project schedule, and care should therefore be taken to enter into appropriate procurement contracts. Vast investment is needed in order to secure nuclear power plants and to commit to building a fleet of power plants. Such commitment requires confidence and stability, close as-

sociation with government, and the experience of a large utility.

The levelised cost of nuclear power generation is competitive in comparison to other forms of low carbon energy technologies, but nuclear power has the additional advantages of providing a reliable base load power and also being a fully proven electricity generation technology in terms of supply reliability.

Most nuclear power plants operating today were financed and built in a regulated environment, thus they are guaranteed future customers and tariff stability, while ensuring a profitable rate of return. The successful financing of nuclear construction is highly dependent on the project structure with the lowest possible financing costs. A large part of government's role in nuclear power financing is to reduce finance risks. Political risk is a major concern for investors and lenders. Stable and efficient regulatory and tax regimes are essential elements of political stability. The extended construction period of between 42 and 60 months can lead to very high interest costs.

¹ (<http://www.world-nuclear.org/info/inf01.html>)

The nuclear power plant chosen should be of proven technology and established design. Key licensing issues should be identified and resolved prior to construction. An efficient and auditable design change process must be put in place to ensure exact replica nuclear plants, compliant with regulations. The Fukushima Daiichi incident has brought about increased awareness and understanding of the earthquake and tsunami risk to be factored into the seismic design and qualification of buildings.

The operating performance of nuclear energy has shown improvement internationally, with an increased share of total electricity production from nuclear energy. The cost of electricity production from nuclear energy (excluding the cost of capital) in the United States (US) has decreased slightly, while electricity production from oil and gas have increased substantially in the US between 1995 and 2008 (Figure 2.2).

Licensing

The nuclear industry has come to recognise that it can contribute to stability and smoothness in the regulatory process by achieving greater constancy in reactor designs. The new approach moves all design, technical, regulatory and licensing issues to the beginning of the licensing process. Safety and environmental issues must be fully addressed before construction begins and before any significant capital spending takes place. Strictly defined timeframes should be enforced for public hearings and consultations in order to avoid delays caused by the public interventions. Adequate staffing of the National Nuclear Regulator (NNR) is important to ensure timely decisions.

In terms of procurement and contracting, the vendor must understand and take national regulatory practice seriously in order to ensure smooth progress of the project. Vigilance is required in order to minimise risks during the construction phase. These

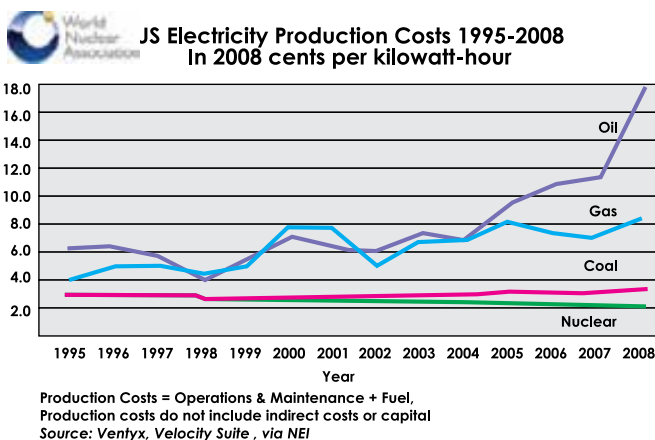


Figure 2.2: United States electricity production costs 1995-2008²

² <http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/uselectricityproductioncosts/>

risks should be covered by contractual arrangements and should be shared between the parties involved. Major components must be ordered several years in advance. The lack of suitably qualified and experienced personnel to support the nuclear programme is a very critical issue.

Risks related to project execution include costly delays due to problems with design, equipment supply, project management, construction and commissioning. New construction and manufacturing methodologies, such as modularisation, can help to limit project risks. Effective project management and diligent contract management are essential. Operations can benefit from the sharing of information and technical assistance with professional associations such as the World Association of Nuclear Operators

(WANO). Decommissioning, waste and spent fuel must be managed within a sound regulatory framework.

Conclusion

It is clear that the drivers for nuclear power are strong, particularly in terms of reducing carbon emissions. There are opportunities for local suppliers to join the international supply chain in the procurement of technology for nuclear new build. Standardisation of reactor design requirements contributes to increasing safety and stabilisation of the economics. Industry needs to cooperate in areas of common interest and maintain strong performance in terms of safety and economics. Most importantly, leadership by government is critical to the successful planning, construction and operation of nuclear power plants.

3

Lessons Learnt from the Fukushima Daiichi Nuclear Power Plant Accident

Prof Hideki Nariai,
Science Council of Japan

Earthquake and Tsunami, 11 March 2011

Japan suffered a great disaster when a large earthquake and tsunami hit its north-east coast on 11 March 2011. These natural events caused a severe accident affecting three reactors at the Fukushima Daiichi nuclear power station. Japan is in the process of recovering from the disaster, and it is now possible to look back at the lessons learnt from the accident.

Japan is located off the east coast of Asia, facing the Pacific Ocean. The epicentre of the earthquake was located near the deep oceanic trench along the east coast of Japan (Figure 3.1). The earthquake, with a magnitude 9.0, was

the fourth largest ever recorded and beyond the scope of recent seismological assumption. The earthquake struck north-eastern Japan at 14:46 on 11 March 2011. Several waves of a large tsunami hit the coast of the Tohoku and Kanto area of Japan between 40 minutes and one hour after the first earthquake, killing more than 15 000 people. Close to 4 000 people are still missing. The earthquake and the ensuing tsunami led to the accident at Fukushima.

In Japan, nuclear energy accounts for almost 30 per cent of the country's total electricity production. Prior to the Fukushima accident, Japan had 54 operational nuclear reactors: 30 boiling water

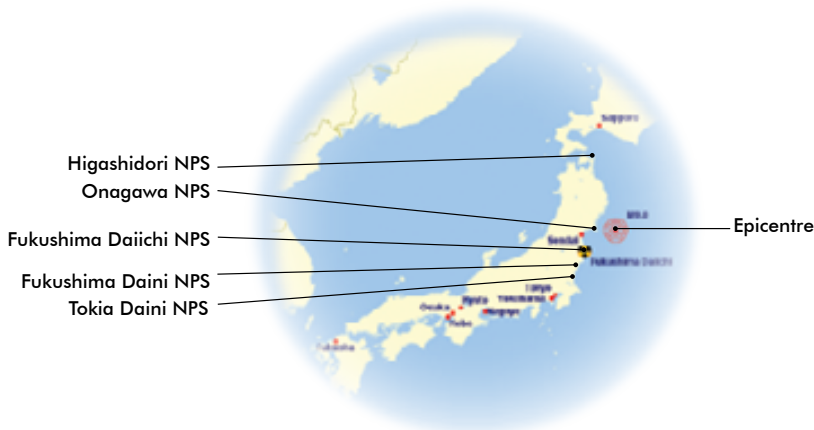


Figure 3.1: Location of 11 March 2011 earthquake and nuclear power stations

reactors (BWRs) and 24 pressurised water reactors (PWRs). In the affected area, 15 BWR plants were in operation. Most of them were brought to cold shutdown status within several days of the natural events. However, the tsunami caused fuel meltdown of three reactors in the Fukushima Daiichi Station.

Fukushima Daiichi is one of the oldest nuclear power stations in Japan. The first plant, Unit 1, was constructed by General Electric, and commissioned in March 1971. Additional reactors, Units 2 to 6, were constructed in sequence by Toshiba and Hitachi under contract from General Electric. The last (Unit 6) was commissioned in October 1979. At the time of the March 2011 earthquake, three of these plants were operating. The other three had been shut down for periodic inspection. The six units differed in terms of reactor model, containment types and electric outputs and had undergone improvements over time.

Accident Sequence

The three operating plants (Units 1, 2 and 3) were shut down automatically on automatic detection of the earthquake. As all external electric power was lost as a result of the earthquake, emergency diesel power generators started up in order to power the cooling system used to cool down the heated fuel assemblies. The 10 m retaining seawall could not prevent the 15 m tsunami waves from hitting the plants, thus disabling the emergency diesel generators needed to cool the reactors 1 to 3 and the used fuel in the Unit 4 fuel pool. All alternating current (AC) power was lost, as well as the ultimate heat sink.

Only one emergency diesel generator was functioning in Units 5 and 6. The cooling systems for Units 1 to 3 had not functioned for some time when the most severe condition for nuclear power plants, the heat-up and meltdown of the fuel, occurred.

The Unit 1 reactor was immediately shut down (scrammed) by the earthquake, and the two emergency diesel generators started up. The isolation condenser (IC) automatically started in order to cool the fuel assemblies but was stopped manually because the cooling rate was too high. After the IC was stopped, a large wave from the tsunami hit the plant and the emergency diesel generators stopped working. All AC power was lost and the reactor fuel could not be cooled. The ultimate heat sink was also lost. The temperature of the fuel rose, thus generating hydrogen by the zirconium-water reaction. It is estimated that the fuel started to melt on the evening of 11 March almost four hours after the tsunami struck the plant.

A considerable amount of melted fuel moved to and accumulated in the bottom of the reactor pressure vessel. The bottom of the pressure vessel was damaged and some of the molten fuel leaked out and accumulated on the dry well floor. Wet well venting was carried out because of the increased pressure in the containment vessel. A hydrogen explosion then occurred in the reactor building, destroying the structure.

The process of Unit 2 followed the same sequence as Unit 1, the only difference being that the reactor core isolation cooling system (RCIC) functioned for three

days in Unit 2. A feed and bleed operation was conducted. Feeding water into the reactor with the RCIC led to a rise of steam pressure and steam was exhausted into the water of the suppression pool. The temperature of the suppression pool increased to almost saturation and gradually steam could no longer be condensed. The fuel assemblies were exposed and, on the evening of 14 March, the core started melting. Molten fuel accumulated at the bottom of the reactor vessel. A containment vent procedure was prepared but a sound of an explosion occurred during the morning of 15 March. There is a possibility that an explosion occurred around the torus room of the containment vessel, but the building was not destroyed.

Unit 3 followed the same sequence as Unit 2. The RCIC functioned but stopped at about noon on 12 March. The High Pressure Coolant Injection system (HPCI) started automatically but then stopped on the afternoon of 13 March. After six hours the fuel was exposed and started melting. The melted fuel accumulated at the bottom of the pressure vessel, and the wet well vent was carried out. A hydrogen explosion occurred in the Unit 3 reactor building, destroying the structure.

Unit 4 reactor was shut down for periodic inspection when the earthquake and tsunami struck. The nuclear fuel had been transferred to the spent fuel pool. Both the cooling and feed water functions for the fuel pool were lost. An explosion occurred in the reactor building on the morning of 15 March. It is thought that there had been an inflow of hydrogen from Unit

3 as the Unit 3 vent line joined the vent line from Unit 4 upstream of the common exhaust stack.

Water was injected to cool the reactor cores of Units 1 to 3 and also to cool the spent fuel pools of Units 1 to 4. A large amount of water was injected into the reactor cores even though it was leaking outside the containment vessel. The leaked water accumulated in reactor buildings and turbine buildings. Highly contaminated water accumulated in the power cables pit near the intake channel and flowed into the sea. The outflow was halted by stopping the discharge process and a silt barrier was installed.

The sequence of events relating to the other 11 reactors including Fukushima Dai-ichi Units 5 and 6 was as follows.

- The operation or otherwise of the external AC power supply, the emergency diesel generators and the residual heat removal system (RHR) was crucial for the plants' ability to reach cold shutdown status, thereby playing an important role in the outcome of the accident.
- Onagawa Units 2 and 3, and Fukushima Daini Unit 3 reached cold shutdown status on 12 March because the external AC power, RHR, RCIC and other cooling systems functioned correctly, although a temporary cable had to be installed to run the RHR in Fukushima Daini units 1, 2 and 4 to reach cold shutdown status on 14 or 15 March.
- The external AC power supply was lost in two of the operating plants, Onagawa Unit 1 and Tokai Daini but the

emergency diesel generators and RHR functioned correctly. The two plants reached cold shutdown status on 12 and 15 March respectively.

- The external AC power supply did not work at the three plants that had been temporarily closed for periodic inspection. Fukushima Daiichi Units 5 and 6 reached cold shutdown status on 20 March with the use of the emergency diesel generator and the RHR system. The situation with regard to the Higashidori Unit was not serious, as the fuel assemblies were outside the reactor.

Evacuation of Residents

In terms of the emergency response to the accident and the evacuation of residents in the Fukushima area, the Tokyo Electric Power Company (TEPCO) recognised that the injection of water via the emergency core cooling systems was problematic at Units 1 and 2. On the evening of 11 March, TEPCO notified the government of the need to declare a state of nuclear emergency in accordance with the special law of emergency preparedness for nuclear disasters. Subsequently, the Japanese Prime Minister declared a state of nuclear emergency and established national and local nuclear emergency response headquarters. At 21:30 on 11 March, an evacuation area was established within a 3-km radius. The stay-in-house ('sheltered') area was established within a 3 to 10-km radius.

As a result of the escalation of events, the evacuation area was extended to a 20-km radius on the evening of 12 March.

The stay-in-house area was extended to a 30-km radius on 15 March. Additional evacuation areas were established at a later stage. Evacuation and stay-in-house instructions were promptly carried out in a concerted effort by residents, local government, police and other authorities. About 78 000 people were evacuated from the vicinity of the power plant. Residents will only be able to return to their homes when the environment has recovered from the nuclear disaster. Most importantly, radioactive concentrations in the soil and concentrations of radioactive materials in the air have to be controlled. The soil and environment must be decontaminated and recovered. The tedious decontamination process had already begun.

Recovery Plan

On 17 April, TEPCO announced a roadmap for the restoration and recovery from the Fukushima Daiichi NPS accident involving the stabilisation of the reactors and spent fuel pools and the mitigation of the release of radioactive materials. Every effort was to be made to enable evacuees to return to their homes and for safety and security to return to the lives of all citizens. The restoration roadmap set two targets, namely:

- The steady decrease of levels of radiation to reach normalisation within a period of three months.
- The controlled release of radioactive materials and cooling of reactors to bring them to cold shutdown and so significantly curtail the radiation dose within a further period of three to six months.

In order to achieve these targets, several activities had to be carried out, the most important of which were:

- fuel cooling by minimum water injection;
- transfer of accumulated water in the basement of the turbine buildings into temporary tanks and the installation of a circulation-type water purification system;
- construction of a cover for the destroyed reactor building.

On 19 July 2011, TEPCO announced that the first target had been accomplished. The temperature at the bottom of the reactor pressure vessels had been maintained at 100–120°C and by the end of September 2011 had fallen below 100°C. Radiation dose-rates had declined and the external dose-rate at the site boundary was approximately 1.7 mSv/y (millisievert per year) at most and was continuing to decrease. In terms of the second target, the release of radioactive materials was under control, and the radiation dose was significantly reduced.

The large amount of contaminated water in the turbine buildings and in the pits presented a major problem. In order to re-use the decontaminated water for cooling of the reactor core, a water processing facility had been constructed and was in operation, producing almost 90 000 tons of processed water by the end of September 2011 (Figure 3.2).

Measures taken in respect of Fukushima Daiichi Units 1 to 4 included:

- Reactor cooling by circulating water via the turbine hall basement along with the treatment of high-level radioactive wastewater.
- Spent fuel cooling using a heat exchanger.
- The installation of a ground water barrier wall to mitigate contamination of the sea through underground water.
- Installation of covers over the highly damaged reactor buildings in order to prevent further release of radioactive materials.
- The cover of the Unit 1 reactor building underway.

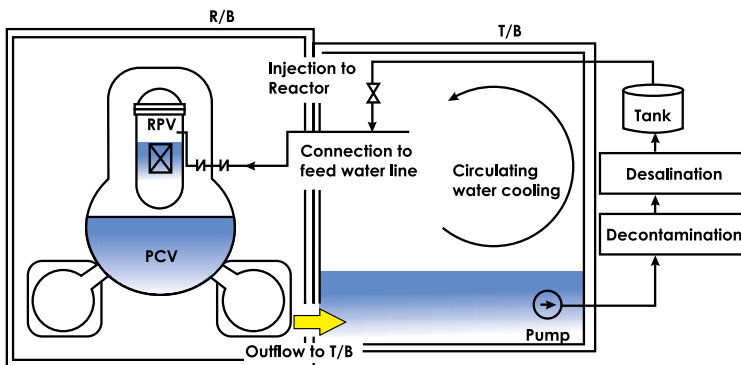


Figure 3.2: Improved reactor cooling system
(Source: TEPCO Press Release, 2011)

Lessons Learnt

The Japanese government reported on the lessons learnt from the accident to the IAEA Ministerial Conference on Nuclear Safety. The 28 lessons are divided into the following five categories:

Category 1:

Strengthening preventive measures against a severe accident.

The reactors should be sufficiently protected to avoid serious accidents resulting from natural disasters such as earthquakes and tsunamis. Although the reactors and major equipment survived the earthquake, the external power supply was damaged. The design guideline should take into account the loss of AC power over a longer period. An alternative water injection system should take into account the lack of power and a high-radiation environment.

Category 2:

Enhancement of response measures against severe accidents.

Countermeasure for hydrogen explosion outside the reactor containment vessel, not only inside the vessel, should be considered in the design.

Category 3:

Enhancement of nuclear emergency response to nuclear disasters.

To provide for large-scale natural disasters and protracted nuclear accidents.

Category 4:

Strengthening of safety infrastructure, specifically the legal framework and safety regulatory bodies.

Provision of criteria and guidelines and adequate human resources. Several as-

pects regarding safety have not been enough in Japan. Research in relation to severe accidents has decreased gradually in these ten years.

Category 5:

Thoroughly instil a culture of safety.

It is anticipated that the Fukushima accident will inspire a new culture of nuclear safety.

The government initiated an investigation into the following matters to implement the lessons learnt:

- An overall safety evaluation of the robustness of existing nuclear power plants, particularly safety during, or as a result of, natural disasters, including loss of all AC power and the ultimate heat sink. The evaluation should identify potential weaknesses in the plants by assessing safety margins relating to external events.
- The revision of safety design guidelines such as guidelines relating to seismic safety and severe accidents.
- The reorganisation of the regulatory bodies at the Ministry of the Environment would be completed by April 2012.

The Investigation Committee on the Accident at the Fukushima Nuclear Power Station was established and tasked to perform a comprehensive investigation to identify the root causes of the accident. The committee has already held three meetings and an intermediate report will be made available at the end of 2011. A final report will be produced in summer 2012.

Some fundamental points concerning the accident are:

- The first nuclear power plants in Japan were introduced from the US as part of turnkey contracts with GE (BWRs) and Westinghouse (PWRs). The US companies developed the BWR and PWR systems by conducting research and development (R&D), including numerous fundamental experiments. Although Japan had started nuclear research in 1954, it lacked basic R&D experience, particularly with regard to the treatment of radioactive material and emergency conditions.
- The first plant was planned and constructed more than 40 years ago before extensive knowledge of earthquakes and tsunamis was available. Scientists at that time said that the highest tsunami would be almost 2 to 3 m and the plant was designed and constructed accordingly.
- The complicated systems of nuclear power plants require expertise and co-operation from the broad field of technology.
- The fact that Japan is a highly developed, industrial country enabled it to

manage the accident. A strong scientific and technological base is essential in order for a country to cope in times of disaster.

The accident was extremely severe and had serious consequences. Many important lessons have been learnt. These must be shared with the international community in order to contribute to the enhancement of nuclear safety around the world.

Japan would like to express sincere gratitude for the international support received during this disaster. The assistance provided by South Africa, particularly the rescue teams who participated in the search and recovery exercise after the disaster, is highly appreciated.

References

TEPCO Press Release (2011) in Home Page: Progress Status of "Roadmap towards Restoration from the Accident at Fukushima Daiichi Nuclear Power Station on August 17".



Challenges and Opportunities for Enhancing the Safety Standards in the Nuclear Industry

Prof Robert Guillaumont,

Academie Des Sciences, Institut de France

(This presentation is based on the French Academy report *Solidarité Japon* of June 2011)

Nuclear Safety Standards

The International Atomic Energy Agency's (IAEA's) Nuclear Safety Standards (NSS) are documents of fundamental principle designed to ensure that nuclear safety objectives are achieved. NSSs can be advisory or compulsory and are normally laid down by an advisory or a regulatory body in the country concerned. **Nuclear safety objectives are expressed in general terms and are not concerned with specific methods of implementation.**

Most of the IAEA's NSS are not legally binding but are considered to be international references (as are the recommendations of the International Commission on Radiological Protection) for radioprotection leading to basic safety standards. The organisation of nuclear safety depends on the sovereignty of each country. There is no international nuclear safety authority. The World Association of National Operators (WANO) aims to enhance nuclear safety worldwide. International organisations (for example Organisation for Economic Co-operation and Development Nuclear Energy Agency and IAEA) and

transnational organisations (European Nuclear Safety Regulators Group, Western European Nuclear Regulators Association and Heads of the European Radiological Protection Competent Authorities) try to harmonise regulations and practices.

Nuclear safety includes three fields:

- the safety of installations;
- the radioprotection of all groups; and
- the safety of the public in the case of accidents ranked between 5 to 7 on the International Nuclear Events Scale.

The basic strategy of nuclear safety is to prevent exposure to radiation, to prevent uncontrolled dispersion of radioactive substances and, in the case of an accident, to take countermeasures to mitigate the effects. This strategy applies to all installations in the nuclear fuel cycle, from uranium mining to nuclear waste management, and takes into account all possible natural and anthropogenic events that cause fatalities.

The radioactive matter that presents the highest potential hazard is irradiated nu-

clear fuel. As its burn-up increases, so the levels of fission product activity, plutonium (Pu), minor actinides increase. Its radioactivity increases from kBq/cm^3 to several tens of Ci/cm^3 , and its residual thermal power output increases from 0 to approximately 100 W/cm^3 .

Worldwide, there are very high levels of movement and storage of radioactive matter. About 10 000 tons of spent nuclear fuel is discharged from nuclear plants each year. Nuclear reactors and reprocessing spent fuel facilities are the major challenges to nuclear safety. The event of greatest concern is the nuclear core meltdown.

The NSSs are well established in the nuclear industry, based on lessons learnt from 14 000 operating reactor-years all around the world and from minor incidents and major accidents that have taken place at nuclear power plants, notably at Three Mile Island and Chernobyl.

In principle, NSSs represent the state-of-the-art in terms of nuclear safety.

The safety of most Generation II reactors has been improved in the light of feedback received from the Three Mile Island accident in 1979, for example in respect of the provision of essential power and cooling water, but only Generation III reactors have additional built-in safety, such as the containment of corium and the ability to withstand a large plane crash. Both are major improvements that should reduce the need to evacuate people and to control the sale of goods. The principal safety features of the Generation III European Pressurised Reactor are shown in Figure 4.1.

Improvements in nuclear safety are of particular interest and concern to:

- operators who are responsible for the nuclear safety of their installations;
- nuclear safety authorities;
- other authorities in charge of public safety.

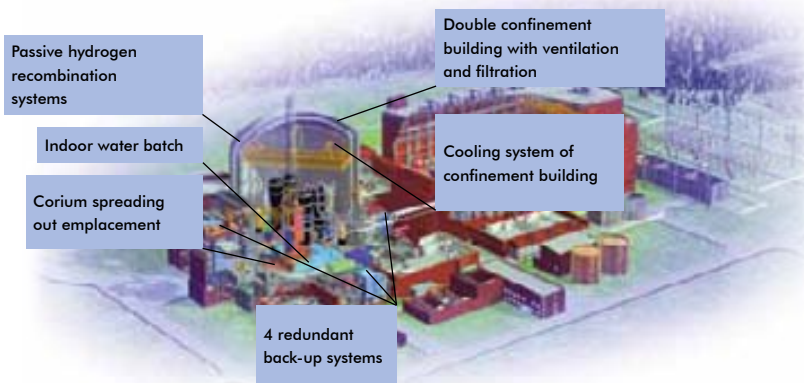


Figure 4.1: Principal safety features of the Generation III European Pressurised Reactor
(Source: Adapted from Areva and EDF Group)

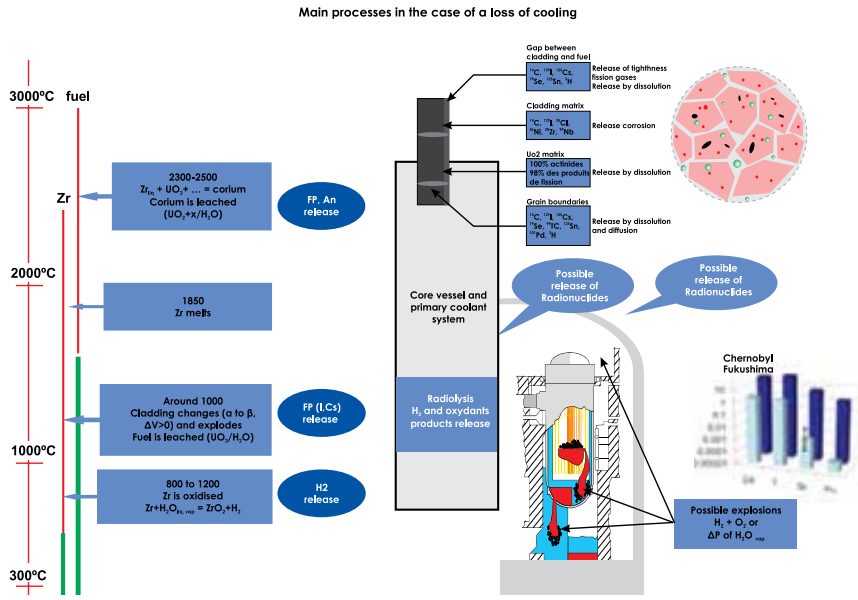


Figure 4.2: Main processes in the case of a loss of cooling
(Source: Adapted from different sources)

Since the Fukushima accident, many countries have indicated the need to review and upgrade the NSS.

Challenges

Designs of installations and plans to prevent and/or mitigate accidents stem from a deterministic and/or probabilistic Safety Case Analysis (SCA). This leads to an evaluation of the risks and the steps to be taken to mitigate the risks. The SCA addresses the planning and the coordination of the emergency and post-accident periods particularly in respect of radiation exposure. With respect to reactors, the SCA should take into account the physical and chemical phenomena that occur during an accident, the characteristics of the dispersed radioactive matter,

the characteristics of the contaminated areas, and the hazards of radioactivity.

Some of the phenomena to be considered are illustrated in Figures 4.2 and 4.3. Considerable research has already been conducted in relation to nuclear safety, both on a national and international level. Nuclear safety refers not only to basic safety functions, rules and regulations, but also to scientific evaluation. Any advancement of the basic knowledge of the behaviour of nuclear fuel, or improvement in the management of nuclear accidents, will contribute to the improvement of NSS.

Each accident stimulates research in the field of nuclear safety because it brings to light new scientific and societal phenom-

end. The Fukushima accident confirmed what was known about the behaviour of non-cooled nuclear fuel and revealed the kinetics of the irreversible processes that can occur. The accident has emphasised:

- That independent events of a very low probability can occur quasi-simultaneously, presenting the challenge to re-examine the SCA methodology to take into account such events as potential initiators of a serious accident.
- The difficulties related to cooling the nuclear fuel (in the reactor core and used fuel pools). The challenges presented concern assuring additional internal and external water reserves, limiting the quantities of fuel assemblies in reactor pools, and considering a containment system for potential radioactive emission from these facilities.
- Radioactive waste production, including contaminated water, can be important and can become a major problem to society. The challenges are to manage these wastes without

delay in order to avoid dissemination of radioactivity and to decontaminate water for recycling.

- The difficulties of controlling chemical hazards, such as the explosion of hydrogen. The challenge is to install large capacity plant to manage hydrogen (passive recombination) and to control the cooling of corium.
- The emission of radioactive substances to the local environment can last a long time, without the dilution that occurs in the case of long-distance transportation. The challenge is to model the short distance transport and the deposition of radionuclides.
- The necessity of decontaminating large areas in order to allow residents to return quickly to the area. The challenge is to find decontamination methods that will not spread the radioactivity to other areas.

The Fukushima accident has revealed new phenomena related to the reaction of hot fuel with water, of corium with water and concerning the radiolysis of water

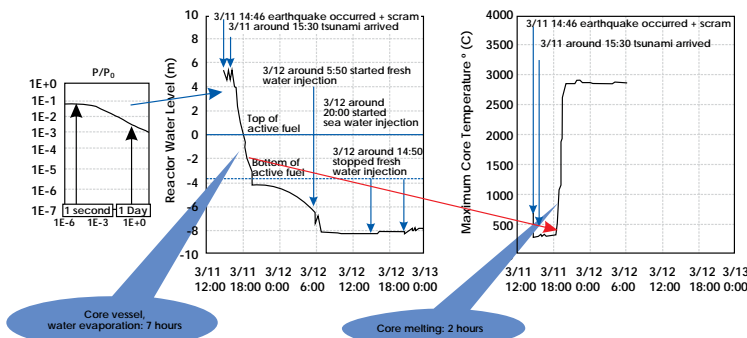


Figure 4.3: Fukushima data showing the kinetics of irreversible events
(Source: Adapted from TEPCO)

at a very high temperature. The accident has given rise to questions concerning:

- The validity of probability estimates of a severe nuclear accident. The probability of core-melt is above 10^{-4} per year.
- The safety of nuclear energy.
- The transparency and credibility of information.
- Decisions taken by the authorities in terms of managing the accident.

Opportunities

The Fukushima accident has not called the NSS into question, but does suggest that the NSS should be applied with increased rigour and that some aspects of the NSS should be improved.

Fukushima presents opportunities to:

- increase the pool of national and international independent experts;
- connect national safety organisations to enhance and share expertise
- increase the credibility of the SCA and make it comprehensible and known to the public;
- check the capacity of reactors to resist unanticipated events at design inception;
- prioritise and support basic, applied and technological research in nuclear safety, merging operators, specific safety organisations and academic research organisations.

Research

Research should be enhanced in the following areas:

- The probability of the occurrence of natural and anthropogenic events.
- Radiology:

- o radiobiological effects of low doses (re-examine the linear no-threshold theory);
- o effects of chronic low doses;
- o dose limits for intervention and/or evacuation and for iodine distribution.
- Management of accident remediation:
 - o rapid and complete characterisation of the contamination of soils;
 - o rapid and complete characterisation of contamination of living materials, particularly population dose evaluation;
 - o large reduction of the contamination of soils;
 - o behaviour of iodine and caesium in recycled materials;
 - o establishment of a crisis epidemiology system to identify and follow-up exposed people.
- Current reactors:
 - o ageing of components (for example reactor pressure vessel and cables);
 - o prevention of chemical hazards (hydrogen explosion);
 - o viability of systems;
 - o human and organisational factors.
- Severe accidents:
 - o Basic research into:
 - fuel behaviour at high temperature and corium formation;
 - physiochemical properties of fission products and transuranic elements;
 - transport of radionuclides within the core, the primary circuit, the containment and the environment;

- modelling the dispersion of radionuclides in the near and far field according to weather forecasting.
- Technological research into:
 - loss of cooling and insertion of reactivity;
 - behaviour of corium in contact with steel, water and concrete.
- Innovation in various areas, such as new materials, new cladding, new fuels, wireless transmission of measurements, remote control of reactor operations and sarcophagus safety.

Conclusion

The international community should progress into the future by agreeing to:

- increase the role of IAEA;
- enhance cooperation with regard to nuclear safety: peer review can reveal incipient failures;
- apply and enhance common NSSs and basic safety standards;
- base the SCA on a scientific approach as well as on regulatory requirements;
- strongly support research in nuclear safety.



Challenges and Opportunities for Enhancing the Development of Safer Nuclear Energy Technologies

Prof Rob Adam,

CEO, South African Nuclear Energy Corporation

Challenges for Nuclear Power

Nuclear Fuel Resources

One of the challenges for nuclear power is the perception that global uranium resources are only enough to supply fuel for the next 100 years. This issue is often raised by the environmental movement. However, new uranium discoveries are being made on a yearly basis and, as nuclear energy returns to the agenda, exploration by mining companies will continue to source more uranium. New technologies could enable the extraction of uranium from sea water. 25 billion tons of uranium in the Earth's oceans would fuel the world's current nuclear fleet for about 7 million years!

Further, thorium can be used to breed ^{233}U to double the world's current nuclear fuel material reserves, and would remove many safeguard challenges. India, having the largest reserves of thorium in the world, is making progress in this area: It is necessary to link the thorium reactor programme to the uranium programme, because it would be necessary to build a stockpile of ^{233}U .

Currently only ^{235}U is 'burnt' in reactor fuel but only 0.7 per cent of natural uranium consists of ^{235}U . The other 99.3 per cent is ^{238}U which remains 'unburnt' and ends up in spent fuel. Spent fuel is not to be considered waste since it contains a huge resource, namely the unburnt ^{238}U and plutonium isotopes. Fast breeder reactors convert ^{238}U into ^{239}Pu , thereby potentially increasing the world's burnable uranium stocks by a factor of over 100.

Fusion

There is also increased interest in fusion technology. All current nuclear electricity generation is fission-based. Nuclear fusion, however, offers almost limitless fuel reserves in the form of lithium and water. The global research collaboration International Thermonuclear Experimental Reactor is the world's response to the fusion challenge. The challenge in relation to fusion is that, in overcoming the electrostatic repulsion between tritium and deuterium nuclei, which requires very high temperatures, these nuclei generate their own magnetic fields, which cause 'leaks' in the applied field confining them. A solution could be to fuse neutrons from a fission reactor with helium-3 (^3He).

Unfortunately, naturally occurring ^3He is extremely rare, but there are millions of tons of it on the moon, occluded in ilmenite rock. There is a theoretical possibility of fusing ^3He nuclei (to give ^4He plus two protons), albeit at very high temperature. ^3He would constitute an entirely radiation-free nuclear fuel. This would require International Thermonuclear Experimental Reactor's involvement.

Spent Fuel

Spent fuel represents a further challenge. It is necessary to develop a plan for its management. Although the amount of spent fuel is much less than ash and greenhouse gas emissions from coal-fired plants, concerns remain that the nuclear industry has an incomplete business plan. As yet, very few countries internationally license long-term spent fuel repositories. It is crucial to initiate a realistic, ongoing plan for spent fuel for immediate implementation.

Technologies exist that are in theory capable of almost closing the fuel cycle by burning all radionuclides to non-radioactive products in fast reactors, thus significantly reducing the waste volume to a small percentage of shorter-lived non-fissionable nuclides. Using a particle accelerator, the remaining radioactive nuclides can be transmuted to non-radioactive nuclides. The costs of finding long-term solutions to challenges relating to spent fuel waste are considerable. Several current research programmes are devoted to these long-term projects.

Public Perception

Some of the issues relating to the public perception of the nuclear industry, particularly

following the Fukushima accident, are:

- The nuclear industry is its own worst enemy in that it apologises for everything, thereby appearing to take the blame.
- The nuclear industry suffers from 'over-the-top' syndrome. When you apply for a licence to bury something 800 m underground, will anyone believe you when you say it's more or less harmless?
- Lessons should be learnt from nuclear accidents and from how other industries manage their accidents. Do not promise the public that there will never be another accident.

Where are we now?

There have been three generations of nuclear power reactors, with the fourth still in the concept stage (Figure 5.1). The rough distinctions between the various generations are:

Generation I:

Prototypes and early power reactors.

Generation II:

Commercial designs built on the experience of Generation 1 up to the end of the 1990s.

Generation III:

Evolutionary safety improvements on Generation II, with much lower core damage frequency achieved largely by multiple redundancy of safety systems and passive safety features.

Generation IV:

Revolutionary and futuristic designs including full passive safety, closed fuel cycle and better economics.

There are currently several different designs of operating power reactors, the

most common being pressurised water reactors (265) followed by boiling water reactors (94), pressurised heavy water reactors (44), gas-cooled reactors (18), light water graphite reactors (12), fast breeder reactors (4), and other types (4). There are three main groups of existing reactors currently in the world: North America, Europe and Japan/Korea/Southern China. The locus of new build is moving eastwards, with limited build in Europe and the United States and more in Russia, India, China, Korea and Japan. The west is de-industrialising and can therefore address its CO₂ emission targets by other means. Power reactors currently under construction are pressurised water reactors (50), advanced boiling water reactors (4), fast breeder reactors (2) and other types (1). The greater diversity of designs of the past is shrinking.

What is being done?

The Generation IV International Forum is developing six nuclear reactor systems

for deployment between 2020 and 2030. Three of these are fast neutron reactors. All operate at higher temperatures than today's reactors. In particular, four are designated for hydrogen production. All six systems represent advances in sustainability, economics, safety, reliability and proliferation-resistance. South Africa is one of the 13 members of the Forum that focuses on developing these six designs.

Relative to current nuclear power plant technology, the claimed benefits for fourth generation reactors include:

- nuclear waste that lasts a few centuries instead of millennia;
- one to three hundred times more energy yield from the same amount of nuclear fuel;
- the ability to consume existing nuclear waste in the production of electricity;
- improved operating safety;
- economically more competitive than the current generation.

Generation IV: Nuclear Energy Systems Deployable no later than 2030 and offering significant advances in sustainability, safety and reliability and economics

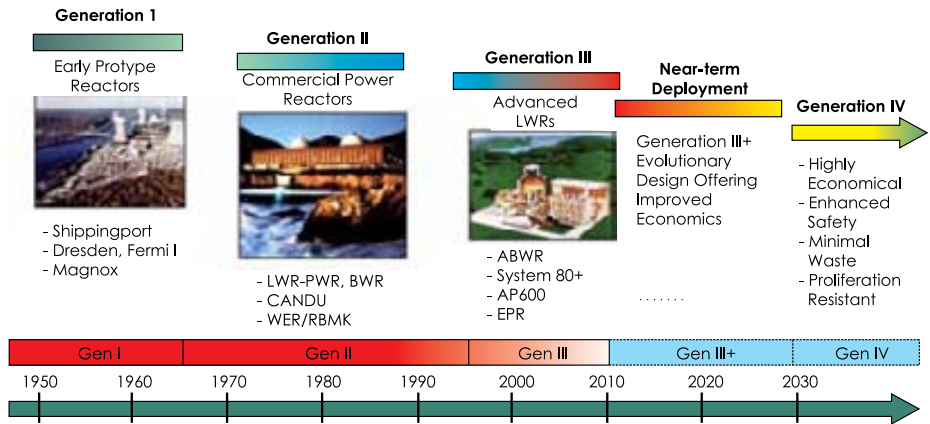


Figure 5.1: Generations of nuclear reactors ³

³ <http://www.cvrez.cz/web/en/node/121>

Opportunities

The further development of nuclear technology in South Africa presents several opportunities including:

- The opportunity to bootstrap South African science and technology on the back of a several hundred billion rand spend on nuclear new build.
- The opportunity for South Africa to be part of a global effort to reduce the carbon footprint of the world.
- The uranium value chain could be used to attract investors to this country given that South Africa has perhaps the sixth largest uranium reserves in the world.
- The opportunity to develop local high-spec manufacturing which would reduce the foreign exchange imbalance resulting from a massive spend on nuclear build.
- Numerous opportunities for the social sciences to make a practical contribution in the realm of public opinion and understanding.



Nuclear Energy Safety: A Systems Approach

Prof Piet Stoker,

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Background

The International Atomic Energy Agency (IAEA) has no jurisdiction in any of its member states. It provides safety requirements and guidelines, and member states are left to establish their own legislative system to ensure a high level of safety for the protection of people and the environment.

IAEA safety requirements and guidelines are contained in approximately 125 documents, ranging from 30 to 300 pages each, and most have in excess of 20 references. At a reading rate of 10 minutes per page, it would take 41 years to read through the complete set of documents. The word 'tsunami' is mentioned very few times in the IAEA safety requirements and guidelines.

The report of the Generation IV International Forum meeting in Lucerne in October 2011, by Dr Van Zyl de Villiers of the South African Nuclear Energy Corporation of (Necsa), indicates that mention was made at the meeting that the Integrated Safety Assessment Methodology would not necessarily have identified the unique combination of natural events that led to the Fukushima accident, and that "the challenge remained with the

proper application of methodologies of this nature and not necessarily the methodologies themselves". It was suggested that systems engineering (SE) offered a part solution towards better application of methodologies.

A processes view of SE in Handbook 3 of the International Council of Systems Engineering (INCOSE), portraying the modern approach to SE, indicates that industry should follow a process-orientated approach to design. It distinguishes between processes that must be detailed in the enterprise that is conducting SE supported by agreement processes. The system lifecycle management process calls for process guidelines to be established by the enterprise in support of project processes and technical processes. It is important to note that the stakeholder requirement definition process, the initial stage in technical processes, is followed by requirement analysis, and later by system design or architectural design.

The concept of baseline management in a systems approach is referred to as the 'V' model (Figure 6.1). The model depicts increases in time and maturity of baselines as specified in plans, specifications and

Nuclear Energy Safety - A systems approach

The V model. Baseline management

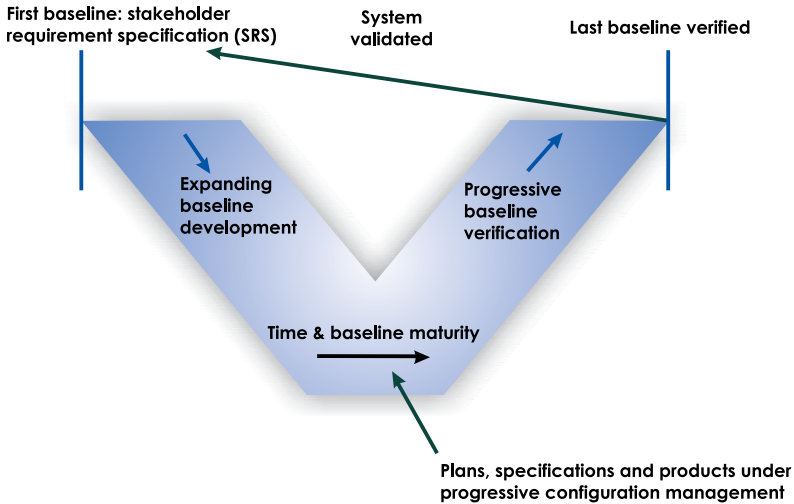


Figure 6.1: Nuclear energy safety – a systems approach

products that are under progressive configuration management. The first baseline, according to a systems approach, is a stakeholder requirement specification (SRS). The last baseline to be verified enables validation of the viability of the SRS. This presents a dilemma in that only after the system has been developed, constructed and commissioned, and production has started is it possible to validate whether the initial specifications are viable.

In applying the 'V' model to the new build programme, it is necessary to:

- Define the 'industrial system'
The industrial system in this instance is the system of interest for nuclear energy safety (NES), comprising the licensee, the system integrator, the nuclear vendor, other vendors, sub-vendors, the nuclear site, plant and equipment,

all documentation, all personnel and all logistics throughout the lifecycle. There are also related systems, such as government departments, legislative systems including the National Nuclear Regulator (NNR), the community, environment and other systems. The system of interest for the system integrator is called the 'plant system', comprising various sub-elements.

- Distinguish safety from safety assurance

In the systems approach to NES it is necessary to be sure that:

- The industrial system produces a safe nuclear plant system.
- The nuclear plant system will operate safely throughout its life.
- The industrial system is capable of supporting the nuclear plant system over its full life.
- The nuclear plant system can be de-commissioned safely.

It should be noted that safety is one of the characteristics of the system, whereas safety assurance is the process whereby safety of a system is systematically monitored, evaluated and improved.

- Achieve safety assurance in the new build

There is only one way in which safety assurance can be achieved for the new build programme, and that is by baselining and formally contracting safety assurance throughout the contracting chain. It follows that the process for monitoring and evaluating safety must be baselined and contracted top down to the lowest contract level. Baselining is a process in its own right, involving many steps, one of which is the identification of the system's stakeholders.

- Identify the new build programme stakeholders

INCOSE Handbook 3 defines a stakeholder as a party having a right, share or claim in a system or in the characteristics of a system that meets that party's needs and expectations. Examples of new build stakeholders are:

- The NNR, as its mandate is assurance of public safety, although it is not part of the industrial system.
- The local community, as locals expect job opportunities and should share in the job-creation characteristic of the system.

The media does not fit the definition of a stakeholder from the SE perspective, but from a project governance perspective, the media is a stakeholder, in the interest of transparency and openness. The IAEA document NG-T-14 with

the title, "Stakeholder involvement throughout the lifecycle of nuclear facilities", makes interesting reading in this regard.

- Apply the baseline management for the new build

The baseline management has its own 'V', and the user requirement specification (URS) is currently being written by Eskom. If the SE approach is followed, a SRS including needs and expectations of all stakeholders is required instead of a URS.

- Share a universal truth that problems downstream are symptoms of neglect upstream. A systems approach should:
 - identify all Nuclear-1 stakeholders;
 - involve the compilation of a SRS rather than a URS;
 - address requirements relating to system safety and safety assurance separately and explicitly.

The lack of visibility and transparency presents a problem that can be overcome by implementing the Inter-Organisational Nuclear Knowledge Management System that is being developed at the North-West University by PhD student, Ms Lúka Potgieter.

Overview of the Inter-Organisational Nuclear Knowledge Management System

SE provides a complete overview of the nuclear industry, its stakeholders, the interaction between stakeholders and the activities. The Inter-Organisational Nuclear Knowledge Management System can be implemented and utilised as a tool to facilitate and observe compliance in the system.

The aim of the project is to create, maintain and operate a web-based knowledge management system for the South African nuclear industry. The objective of the system is to communicate, integrate and facilitate the role and function of all stakeholders in the South African nuclear industry towards successful and cost-effective execution of nuclear projects and operations. The concept for the operation of the system was presented.

In South Africa, the NNR can be viewed as a stakeholder to the nuclear industry system and its operations. The nuclear industrial system consists of Eskom, Necsa, the vendor and sub-contractors. Furthermore, the public, government and other organisations are also external stakeholders involved in the nuclear system. All these organisations formally interact not only with the NNR, but also with one another.

The Inter-Organisational Nuclear Knowledge Management System captures all formal information flow in particular documentation that serves to verify quality and relates to education in nuclear safety between the stakeholders and the nuclear industry by providing:

- Best-practice guidelines on how nuclear energy safety management should take place.
- Real-time facilitation and compliance monitoring of the safety assurance process.
- Auto-verification on the quality of the information flow.

The features of the Inter-Organisational Nuclear Knowledge Management System are:

- It captures business processes of the South African industry at large.

- The system does not interfere with the internal processes of any stakeholder.
- It facilitates formal interaction between industry stakeholders and defines these interfaces in terms of processes between stakeholders, knowledge exchanged within the processes, and deliverables as delivered at the end of processes.
- It organises these processes, knowledge and deliverables in project lifecycle contexts.
- It only captures and integrates those processes, knowledge and deliverables that are designed to defuse across an organisation's boundary.
- When implemented, the system will contribute to confidence building in the nuclear industry.

The value proposition is:

- The system will guide information flow between the stakeholders without disturbing internal workflows of the organisation.
- The system will offer best practice guidelines as baseline for formal information flow.
- The system will ensure that all inter-organisation information flow is visible and transparent to the various parties, aiding informed decision-making.
- The system will continuously keep record of all inter-organisation information flow in order to ensure traceability in the nuclear environment, and could also provide a backup of all inter-organisation information flow.
- The system will therefore provide a communication interface between nuclear stakeholders, ensuring efficient and secure information sharing, even to the public.

Based on the advantages mentioned above, the system and its attributes will build confidence and contribute towards a sustainable nuclear industry.

The question may arise as to how the system could be implemented to not only provide a baseline on what information should flow between whom and when, but also, how it can be monitored and facilitated in real time. The NNR has a responsibility and mandate to ensure safety of the public and the environment. It interacts with the nuclear industrial system through its regulatory framework. The Inter-Organisational Nuclear Knowledge Management System will capture all formal information between the stakeholders, including with the NNR, by guiding the system through its lifecycles. The system will be implemented on a web-based platform linking the stakeholders by providing secure access to the system without compromising their internal business processes.

A helpful metaphor for the system is a spider camera at a football match. It does not participate in the game but continuously hovers above the players, monitoring the game with the rulebook in hand so that it can draw attention to anything that is not according to best practice.

The baseline provided by the system will include:

- Best practice on the processes that should be followed where the stakeholders interact.
- A reference to the quality of information that diffuses across company borders.

The system will make use of artificial intelligence technology to compare real-time information to a database of knowledge, which will be created with input from the NNR. This system will be able to recognise if information in a document lacks valuable information and be able to notify the correct party, improving efficiency of interactions. From a localisation perspective, the system will provide the regulations, standards and specifications that manufacturers, construction companies and maintenance industries will have to comply with.

The following matters required further consideration in the development of the system:

- information overload on the extra-net;
- security of the knowledge;
- maintenance of the system;
- best-practice guidelines;
- governance of the system;
- independence of the Regulator.

Conclusion

The Inter-Organisational Nuclear Knowledge Management System is actively being researched and developed. The proof of concept software solution is being finalised. The ultimate aim is to validate whether the system, as built and as operated, will comply with its SRS. It follows that, according to the systems approach to nuclear energy safety, the ultimate safety and safety assurance of nuclear energy is determined by the first baseline, which is its SRS. It is therefore necessary to:

- specify that ultimate safety and safety assurance of nuclear energy are determined by the first baseline, which is its SRS;

- ensure that it is properly promulgated throughout all baselines;
- ensure that it is properly contracted at all levels;
- ensure that compliance is monitored throughout the project (and system) lifecycles;

- ensure that non-compliance is rectified.

In order for SE to accomplish nuclear energy safety, it is essential that each of these aspects is transparent and visible to all and that there is buy-in from the NNR, Eskom and government.



The Role of Regulatory Authorities in Future Nuclear Energy Safety Development

Adv Boyce Mkhize,
CEO, National Nuclear Regulator (NNR)

Introduction

This symposium provides a platform for a **free exchange of views concerning issues of nuclear safety as South Africa prepares for the nuclear expansion programme and considers consolidating and improving the existing nuclear capacity in the country in the light of many developments in the nuclear industry both regionally and internationally.**

Context for Nuclear Energy Safety

The word 'nuclear' evokes certain memories, more specifically:

- Three Mile Island Nuclear Power Station accident in 1979, as a result of fundamental problems involving hardware, procedures, training and attitudes towards safety complicated by regulatory concerns.
- Chernobyl accident in 1986, which presents a stark reminder of hazards associated with nuclear technology, particularly in terms of the lack of deliberate strategies and systems to proactively and rigorously address the issues of nuclear safety.
- Davis-Besse Nuclear Power Station reactor vessel head degradation in 2002.

- Fukushima Daiichi accident in March 2011.

These accidents create understandable anxiety about nuclear technology. The area of commonality in all the accidents relates to the role (or lack thereof) pertaining to the regulatory authorities. It is therefore appropriate to question the role of regulatory authorities in nuclear energy safety development, as well as take cognisance of the substantial achievements and advancements of nuclear energy and technology. It is interesting that, as in other facets of life, the nuclear industry's clean record and high standing in society can be destroyed by a single lapse. Extra vigilance is necessary, and a deliberate effort must be made concerning matters of nuclear energy safety in order to engender confidence among the public and the authorities.

Role of the Regulatory Authorities

The role of the regulatory authorities is to promote and enforce a safety culture. There is a safety dichotomy in relation to the role of operators as opposed to the role of the regulator. The approach to regulation adopted by the NNR is that

the responsibility for safety lies with the operator. The NNR ensures that the system of safety and operation is adequate and that it meets the demands of safety in line with international best practice. The Institute of Nuclear Power Operations suggests the following definition of a safety culture: “An organisation’s values and behaviours – modelled by its leaders and internalised by its members – that serve to make nuclear safety an overriding priority”.

Although safety parameters may be determined and rigorous controls may be in place, safety systems are not foolproof, and complete safety of a nuclear installation cannot be guaranteed, particularly in relation to imposing elements. It is essential to ensure that mechanisms are in place to prepare for such eventualities, nonetheless the extent of the preparation might still not have taken into account the severity of the impact of unanticipated eventualities. The safety culture should be the underlying premise of the operator.

The role of regulatory authorities covers three major areas:

- Promotional: Encouraging and promoting safety principles and practice, as a voice of conscience.
- Corrective: Providing guidance and support.
- Adjudicative: Intervening decisively in the interest of safety.

A strong safety culture is underpinned by the following principles:

- Everyone is personally responsible for nuclear safety.
- Leaders demonstrate commitment to safety.
- Trust permeates the organisation.

- Decision-making reflects safety first.
- Nuclear technology is recognised as special and unique.
- A questioning attitude is cultivated.
- Organisational learning is embraced.
- Nuclear safety undergoes constant examination, noting that many safety concerns and incidents arise out of complacency.

Global Safety Regime

The International Atomic Energy Agency (IAEA) provides the framework within which the Global Safety Regime operates, seeking to achieve worldwide implementation of a high level of safety at nuclear installations. The framework essentially comprises the activities undertaken by each country to ensure the safety and security of the nuclear installations within various jurisdictions, augmented by the activities of a variety of international enterprises that facilitate nuclear safety.

Several elements cited in the Global Safety Regime framework relate to:

- intergovernmental organisations;
- multinational networks among operators;
- multinational networks among regulators;
- the international nuclear industry;
- multinational networks among scientists;
- international standards setting organisations;
- other stakeholders such as the public, news media and non-government organisations that are engaged in nuclear safety.

The Global Safety Regime is entrenched in several international conventions that

are legally binding on the participating states. South Africa has ratified or acceded to all the conventions, and is therefore obliged to adhere to the highest standards of nuclear energy safety. Central and most important to the Global Safety Regime is a strong national nuclear infrastructure, including an independent Nuclear Regulator. It is recognised that some elements of the Global Safety Regime, although functional today, should be strengthened, especially after the Fukushima accident. These elements are, for example:

- The use of the review meetings of the Convention on Nuclear Safety as a vehicle for open and critical peer review and a source for learning from the best practices of others.
- The enhanced utilisation of the IAEA Safety Standards for the harmonisation of national safety regulations to the greatest degree possible.
- The enhanced exchange of operating experience and the use of this experience for lifecycle management and back-fitting of nuclear facilities, as well as for improving operating and regulatory practices.
- The multinational cooperation for the safety review of new nuclear power plant designs.

The IAEA convened the Ministerial Conference on Nuclear Safety in response to the Fukushima event, which concluded that:

- The IAEA should review and strengthen as appropriate its safety standards related to design requirements with particular emphasis on defence in depth, low probability beyond design basis events, single or in combination, severe accident management,

and measures for single-unit sites and, more especially, for multi-unit sites.

- In response, the NNR requested the operators in South Africa to conduct safety reassessments. The NNR will ascertain the extent to which measures have been put in place to ensure that the facilities are able to withstand extreme external events, a combination of external events, as well as prolonged catastrophes, and provide feedback in this regard. The NNR will ensure that these issues are factored into the design of the new build programme.
- Conventions such as the Convention on Nuclear Safety need to be reviewed taking into account the lessons learnt from Fukushima, particularly in relation to transparency, the independence of regulators, emergency preparedness and peer reviews.
- The international, regional and national emergency and response frameworks should be strengthened.

Role of the Regulator

Section 5 of the National Nuclear Regulator Act (*Act 47 of 1999*) provides that the objectives of the Regulator are, among others, to:

- Provide for the protection of persons, property and the environment against nuclear damage through the establishment of safety standards and regulatory practices.
- Exercise regulatory control related to safety over the siting, design, construction, operation, manufacture of component parts, and decontamination, decommissioning and closure of nuclear installations through the issuance of nuclear authorisations.

- Provide assurance of compliance with the conditions of nuclear authorisations through the implementation of a system of compliance inspections.
- Fulfil national obligations in respect of international legal instruments concerning nuclear safety.
- Ensure that provisions for nuclear emergency planning are in place.

The NNR is prepared for the new nuclear build programme and acknowledges the importance of early engagement with stakeholders, particularly concerning the above provisions in the National Nuclear Regulator Act.

Future Nuclear Safety Development

The NNR safety standards require that the safety demonstration should include both deterministic and probabilistic safety assessments, which have been applied with the licensing of the Koeberg units. The standardisation of designs and harmonisation of standards will significantly contribute to increased safety globally.

The NNR participates in international forums such as the Multinational Design Eva-

luation Programme and IAEA safety committees, and will be reviewing its standards and factoring in the lessons from Fukushima. The principles of continuous feedback relating to improvement and operating experience as part of nuclear safety will be the underlying basis of the NNR operations to ensure a process of continuous improvement. The NNR will also focus on strengthening the regulatory framework, from siting to decommissioning.

Conclusion

It is crucial to make sure that nuclear safety principles are embraced and a continuous learning environment is cultivated by all the players in the nuclear industry. Nuclear energy safety should be placed as an overriding priority in order to engender the level of confidence that the public requires of the industry, and to showcase nuclear technology as a means of enhancing the development agenda and contributing to a sustainable environment. The NNR will endeavour to play this role, rejecting complacency, and confidently face the challenge of ensuring the safety of nuclear energy.



Public Engagement and Perceptions of Nuclear Energy and Associated Risks

Dr Alex Tsela,

CEO, Mzansi Energy Solutions and Innovations

Introduction

The conceptual approach to the debate concerning public perceptions on any subject or technology including nuclear energy is that whatever the public perception is, it is based on an idea. If the public perception is therefore to be changed, it is necessary to understand that it is an idea that is being changed, consequently the approach should entail finding another idea that will be perceived to be more beneficial or superior to the one already held.

Another important aspect concerning public perception, in particular with regards to nuclear technology, is the shifts in paradigm and decision-making factors in the public, as stated by the premises below:

Premise 1:

There has been a paradigm shift in the structure of power in many countries. This implies that there will be a shift in the thinking and decision process regarding nuclear technology and energy. In the past, decisions relating to new technologies were made either by the private sector or politicians with a small group of elite

scientists. Today, there is increased activism by public interest groups and the media, as well as broader legislative involvement and significant judicial intervention. The implication of this shift is that the public can no longer be ignored in decisions processes for a nuclear programme.

Premise 2:

The factors that impact on the future of a nuclear programme are very dynamic. In the past, decisions about a nuclear future were based on standards and technical factors, like economics, technology, etc. This is no longer the case because of increased public interest and activism. Behavioural factors have now to be taken into consideration in making decisions concerning nuclear energy. This implies that the status of public relations divisions should be elevated to a higher level of strategic importance in organisations.

Public Perception of Nuclear Energy

To achieve meaningful public engagement the level of public acceptance should be known or at least inferred. Some notion of the level of public acceptance can be gleaned from surveys conducted in the United States over the last 10 years

by the Nuclear Energy Institute (NEI) and others. The surveys by NEI reveal improved public acceptance of nuclear generation between 1998 and 2010. Approximately 70 per cent of members of the public surveyed in 2010 accepted nuclear as a source of energy generation (Figure. 8.1).

Surveys by Gallup Poll show a similar upward trend, at least from 2001, although there has been a slight decline in public acceptance of nuclear technology since March 2011 (Figure 8.2).

These surveys as depicted by the figures below suggest that the public acceptance was highest around 2010, with some declines after the accident in Fukushima. For countries requiring to engage the public regarding a nuclear programme, these figures raise the following important questions:

- What should be the level of public acceptance of nuclear power required for decision-makers to proceed with or halt a nuclear programme?

- Is it foreseeable that any technology would achieve 100 per cent acceptance from the public in any country?

One hundred per cent acceptance is not even achieved when voting into power a political party, yet political parties take power daily all over the world based on some meaningful public mandate. Similarly, for a country to pursue a nuclear programme, some meaningful level of public acceptance is required.

Managing Public Engagement

It appears that the decision about whether or not a country should proceed with a nuclear programme is a matter of political will based on political interpretation of public perception and acceptance, and on the successful management of activism through, *inter alia*, legislative processes, openness, empowerment and education. This begs the question about who manages activism, and this leads to the concept of public engagement.

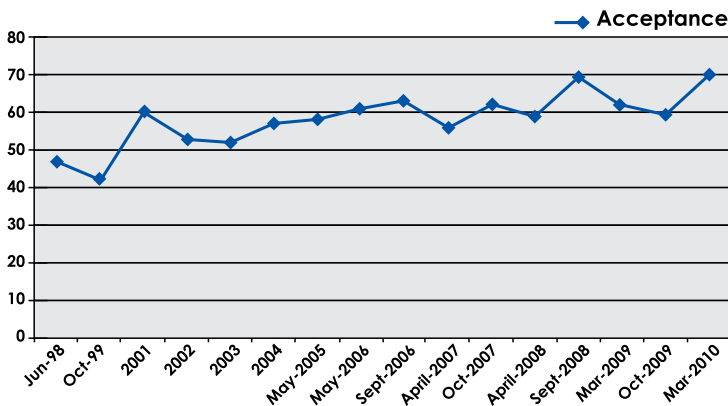


Figure 8.1: Public acceptance survey in the United States, 1998-2010
(Source: Nuclear Energy Institute⁴)

⁴ <http://www.nei.org/resourcesandstats/documentlibrary/publications/perspectiveonpublicopinion/perspective-on-public-opinion-june-2010/>

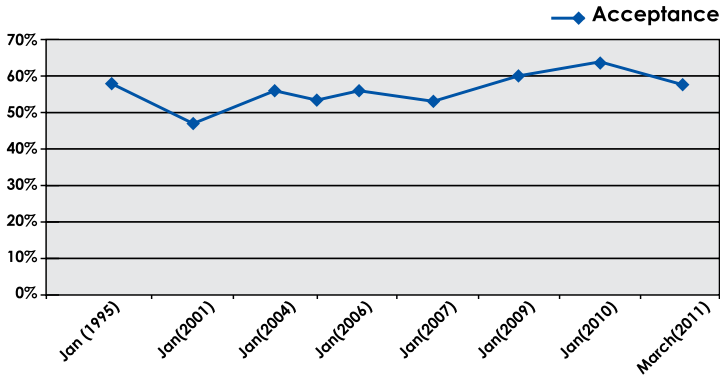


Figure 8.2: Public acceptance survey, 1995-2011

(Source: Gallup Poll results on nuclear energy support published in March 2010⁵, and April 2011)⁶

Managing activism implies engaging people in this process through diverse ways for several reasons. Rationales for public engagement include:

- **Normative rationale:** Ensuring democratic legitimacy of decisions. Policies must be acceptable to the public. They must be seen as 'the right thing to do' in a democratic society.
- **Instrumental rationale:** Facilitating ease of decisions and implementation. When a decision has public acceptance, its implementation also enjoys public support.
- **Substantive rationale:** Ensuring the right choices are made. The public may raise issues that will cause technical people to consider aspects which they might otherwise have ignored, and in so doing may have a better choice of technology.
- **Educational rationale:** Demystifying nuclear energy and technology. An appropriate public engagement should have as its major aspect, an educational drive so that the public may be educated about nuclear energy.

Although there are compelling reasons for public engagement, the challenge lies in the process of engaging the public. Key engagement process decisions include:

- **What to engage on?**
This should be based on a balance between the respect of individual rights and collective interest, which stems from a moral philosophy and from the awareness that public opinion, is dynamic. Most of the engagement should focus on the collective benefit.
- **Who must engage and who must be engaged?**
There should be different levels of engagement, where each level is engaged on the relevant aspect of the nuclear energy debate. The International Commission on Radiological Protection (ICRP) principles for radiation protection provide a framework that can be adapted for guidance in determining how and when to engage with the public. The first pillar of the ICRP philosophy is justification,

⁵<http://www.gallup.com/poll/126827/support-nuclear-power-climbs-new-high.aspx>

⁶<http://www.gallup.com/poll/146939/majority-americans-say-nuclear-power-plants-safe.aspx>

where in the introduction of a nuclear activity is justified in terms of benefit above acceptable risk. In terms of public engagement the level of justification, which concerns the benefits of nuclear energy would entail the policy-maker or relevant wing of government engaging the public to justify the benefit of nuclear within the energy mix. Once justification is established, there is engagement in relation to an optimisation dialogue, which is the second pillar of the ICRP philosophy. The engagement at the level of optimisation, assumes the introduction of nuclear energy has been accepted by the public, and thus the next issue concerns the performance of a particular nuclear energy technology or system with regard to factors such as the parameters of safety, security, etc. At this level of engagement, the public is no longer engaged for acceptance, but rather the technology choice based on parameters. The engaging party at this level would often be the nuclear safety watch-dog (the national nuclear regulator and other state agencies). Innovative ways to demystify nuclear energy and nuclear technology in general need to be developed at the educational level.

- Mechanisms for meaningful and fair engagement.

Practice in the other industries can be instructive to the nuclear and scientific world. One such industry is the transport industry, in particular aviation. It is a known factor that airplane accidents do happen and when they do, many lives are lost, yet the public continues to use airplanes on daily basis. The reason for the continued use is that the

public has been sufficiently engaged to the point of public acceptance of the benefit of airline transport in spite of the known risks. One aspect of public engagement that the airline industry has used, entails first leaving public engagement to be led by public experts not technocrats, and thus creating messages that will clarify the benefit in a language that the public will understand without unduly complicating the message with technical jargon. Recent communication about the introduction of the new A380 fleet of airlines is an example. One of the airlines, Emirates, packaged the message for flights on board the Emirates A380 aircraft that focus on the benefits of flying in the state-of-the-art aircraft. The technological aspects of the aircraft are not overly mentioned to the public. This affirms the importance of using concepts that are in the consumer space when engaging the public.

Conclusion

Some conclusions concerning public engagement and perceptions of nuclear energy and associated risks include:

- The public is rational; it has an opinion and hence has a perception. Opinions and perceptions are dynamic and not conclusive, and public interest is mostly focused on collective benefit.
- Public acceptance of nuclear energy was highest in 2010. It decreased somewhat in 2011 as a result of the Fukushima accident but is recovering. There is no definite measure, apart from political elections, of how much public opinion is sufficient for a decision.

NUCLEAR

- Public engagement must be based on a framework, which addresses as a minimum, what to engage on, with whom to engage and on what, who must engage, and the mechanisms of engagement.
- Nuclear scientists and industry should carry most of the blame for not developing innovative public engagement techniques. Consumer concepts rather than technical jargon should be used to demystify nuclear energy. We

have fuelled a suspicious and possible negative perception of nuclear energy by presenting nuclear as the most dangerous thing there ever was on earth. Perhaps we may wish to blame the way the atomic energy was introduced to most members of the public through the A-bomb, yet we have decades of public benefit use of the same atomic energy which when properly packaged could yield a positive public perception of nuclear power.



Responsible Stewardship of the Nuclear Renaissance: Best Practice for Non-proliferation

Prof Roger Cashmore,

United Kingdom Royal Society, (Presentation via video conference)

Background

The Royal Society's extensive in-depth review of the nuclear fuel cycle came into being because it was recognised that an **expansion of civilian nuclear power programmes** would occur in the world, with some countries embarking on new civil programmes for the first time to help meet their climate change and energy security needs. The so-called 'nuclear renaissance' has renewed debate about the relationship between civil nuclear power and the proliferation of nuclear weapons, as well as other security risks. This project explored the potential of new technologies and new governance practices to make the nuclear fuel cycle, particularly the back end, more proliferation resistant and secure. The Royal Society (2011) report entitled *Fuel cycle stewardship in a nuclear renaissance* made recommendations in this regard.

Best Practice for Non-proliferation

Some comments with regard to best practice for non-proliferation are:

- Civil nuclear power has its history in nuclear weapons programmes in a number of countries, whereas reactors

today are built for civil purposes. The report recommends that all the nuclear weapon states should separate their nuclear weapon programmes from their civil nuclear power programmes, placing the latter under international safeguards to verify this separation.

- There is no proliferation-proof fuel cycle, and there are problems with all the fuel cycles. Hard work is required to ensure that the proliferation risks are reduced. The International Atomic Energy Agency (IAEA) is central to managing dual-use risks. It is important that the additional protocol introduced by the IAEA, giving the IAEA broader inspection capabilities, should detect undeclared facilities. The report recommends that all non-nuclear weapon states with nuclear power should implement IAEA comprehensive safeguards and the additional protocol.
- Proliferation can also occur via personnel and knowledge. The extent to which personnel and knowledge from civil nuclear power programmes assisted nuclear weapon programmes is not clear. Nonetheless, all universities and industries that are involved in the civil nuclear power programmes

should make an effort to develop education and awareness-raising courses for all their personnel.

- The plutonium in the spent fuel should be made as unattractive for nuclear weapon use as possible. This means that the barriers for its use (such as the isotopic and radiation barriers) should be increased. The report recommends that nuclear fuel should be developed and nuclear reactors should be configured to enable the maximum burn up, consistent with efficient and economic operation of the reactor.

A Nuclear 'Davos'

An international nuclear power market, supply chain and services currently exist. Uranium is mined, enriched and fabricated in different countries, and reactors are fabricated in one country and installed and operated in another country. There is also an international market for re-using the spent fuel. Over the last three or four decades, national facilities have moved and are moving from purely state-run to multinational companies, bringing major benefits through:

- increasing transparency and spreading best practice;
- industry's overarching interest in non-proliferation and nuclear security because a single incident from a civil facility will affect the credibility of the industry worldwide.

Global governance does not yet reflect the reality of a fully internationalised fuel cycle. This multinational industry must be part of the solution and not the problem. The report suggests that the United Kingdom government should help to

establish an industry-led activity worldwide, a World Nuclear Forum, in order to interface with political leaders to explore the development of, or responsibilities for, nuclear power.

Integrated Risk Management

In the aftermath of the Fukushima accident, it is important to avoid complacency in all nuclear activities, not only in terms of safety, but also with regard to issues of security and non-proliferation. Moreover, safety, security and proliferation risks should no longer be considered in isolation. The integrated approach reflects an 'all hazards approach' to national security, covering a range of threats from natural disasters to man-made accidents or malicious attacks by states and non-state groups. This integrated approach should be taken into account from the outset, and in the design of the nuclear facilities. Security by design must be introduced and become best practice. The World Institute of Nuclear Security (WINS) brings this aspect to the attention of the industry. Safeguards by design should also be involved from the beginning of any new nuclear installation and should become best practice.

Integration by design allows for synergies to be identified and conflicts to be resolved in advance, to develop the best safeguard system possible.

National Regulation

Safety and security are regulated at national level. The report recommends that safety and security be integrated into a single national regulatory body (NRB). Currently, non-proliferation is regulated

at international level. It is in the interests of national governments to ensure that legislation is in place so that industry supports safeguards in order to avoid false accusations of proliferation. The NRB should serve as the focal point for both industry and the IAEA.

The NRB should act on the IAEA's behalf during a licensing process, and conform to the IAEA activities, which would mean that:

- the licensee understands, and the facility design meets, safeguards both safety and security requirements;
- delays and conflicts with other regulatory requirements would be avoided;
- more efficient fuel cycle designs would be supported.

International Regulation

There is no intergovernmental regulator for safety and security. The IAEA is a source of best practice and advice in these areas. As there is no overarching international regulator, peer review between countries is important to ensure that safety and security become well developed.

An integrated governmental peer-review system is of vital importance. It should include appropriate security information, on a voluntary basis, in national reports submitted as part of the peer-review process for safety, and integrate safety and security into IAEA advisory services for member states.

In terms of integrated industry peer review, the World Association of Nuclear Operators (WANO) runs peer reviews from country

to country, and it would be ideal for the World Association of National Operators (WANO) and the World Institute of Nuclear Security (WINS) to collaborate on joint safety and security reviews. Post-Fukushima, the nuclear industry has been alerted both to problems with the reactor operation and potential problems relating to spent fuel storage.

It is necessary to ensure that everyone becomes as concerned and familiar with non-proliferation and nuclear security issues as with nuclear safety. Security should be introduced as a site licence condition, and operators should become liable for security just as they are for safety. Integrated corporate governance would ensure that the boards of companies operating nuclear facilities have a responsibility for addressing these issues and reporting on them.

Cradle-to-Grave Planning in the Nuclear Fuel Cycle

The management of spent fuel should no longer be an afterthought. The entire fuel cycle needs to be considered from cradle-to-grave at the outset. The multi-decade to century timescales of new nuclear programmes require long-term strategic planning. In order to deal with the extended timescales, countries should:

- Develop a national policy that contains a clear indication of the long-term role for nuclear power in the country's energy strategy, including requirements for sufficient interim storage of spent fuel and the creation of a waste management organisation to deliver disposal of the final high-level waste in a timely way.

- Set up a long-term research and development (R&D) roadmap to support spent fuel management strategies. R&D provides the contingency for addressing unforeseen changes in policy by keeping future management options open.
- Seek international fuel cycle arrangements, especially when a small nuclear programme is being established and there is a lack of national capacity. It is in the interests of all countries with nuclear power to have access to the capacity to manage nuclear material safely and securely for the benefit of all.

International Spent Fuel Management

There is renewed interest in non-proliferation and security benefits of cradle-to-grave fuel cycle services. This notion is not new and relates not only to thermal reactors but also to research reactors. It will become increasingly important when considering small and medium-sized reactors.

International services for re-use have been available for decades. However, large volumes of spent fuel may arise from a nuclear renaissance and may create a commercial market for disposal services. It should be recognised that disposal services will be important particularly for countries that do not have suitable geology and resources to dispose of nuclear materials safely and securely.

International Disposal

This is a longer term prospect given the political sensitivities involved. It is recom-

mended that international disposal may be attractive for many countries, and the way to begin to develop confidence is through partnerships. A group of countries could collaborate on a joint waste disposal programme. Governments should be encouraged to accept the joint waste disposal programmes. One way of developing partnerships is through collaborative R&D, which builds confidence between countries and keeps international options open. In the longer term, R&D partnerships could build trust to foster more integrated policies and collaborative infrastructure.

European Approach

The European Atomic Energy Community (EURATOM) is the best exemplar of a regional approach to fuel cycle management. There was a lack of cradle-to-grave thinking 50 years ago. A regional approach is gradually being developed for the front end, but does not yet exist for the back end, except for the business of reprocessing. A European Community Directive in 2011 requires that all members of the European Union with nuclear power programmes should have a plan for dealing with their spent fuel and radioactive waste, and remarks that sharing facilities for spent fuel and radiation waste management including disposal facilities, is a potentially beneficial option.

EURATOM is the regional mechanism for ensuring the highest standards of safety, security and non-proliferation in member states, and has a close liaison with the IAEA, operating as an IAEA agent. EURATOM has authority to deal with lack of conformity to the nuclear safety standards.

Conclusion

In summary, the report of the UK Royal Society:

- describes the best practice;
- explains international realities of how things have changed in the nuclear industry;
- suggests viewing nuclear safety and security in terms of integrated risk management;
- proposes that independent and transparent regulation activities be set up;
- suggests that the fuel cycle should be managed from the 'cradle to the grave', in an international management manner.

The recommendations of the report should be considered for application in Africa.

Discussion:

Selected Questions and Answers

David Nicolls, Eskom:

- (1) With regard to non-proliferation risks, one of the key issues is to separate civil nuclear programmes from military nuclear programmes. What is the view of the United States (US), given that two of their civil nuclear plants are used for tritium production?
- (2) In terms of nuclear safety, it is interesting to note that the US and European Union (EU) are opposed to international oversight of facilities, in the sense that they appear to view themselves as above the standards of the rest of the world. There is no external review of US and EU nuclear plants.
- (3) It is widely known and accepted that the main problem with Fukushima was that the plant was built too low in the ground.

Response, Ms Anne Harrington:

- (1) The reactors mentioned belong to a government power-producing organisation, and the power goes to the civilian sector. As a G5 nation, the US has a responsibility to maintain a safe and secure stockpile.
- (2) The Nuclear Regulatory Commission has finished its review of the safety elements of the many reactors that are functioning in the US. The Nuclear Regulatory Commission discovered that over time, the safety elements of the plants have been upgraded in ways

that were not applied to plants in Japan. A better channel is needed for exchanging technical information on how to improve safety among operators of similar power plants all over the world.

Response, Dr Hideki Nariai:

- (3) Research was done to estimate how high a tsunami could be and concluded that a possible tsunami wave would not exceed 2.5 m. The decision was taken to build a 10 m-high retaining sea wall. However, the recent tsunami constituted a convergence of waves that reached well over the height of the wall. Building on high ground is also a problem for various reasons. There are still many lessons to be learnt.

Prof Rob Adam, Necsa:

What does Mr Tshelane think the stumbling block would be in South Africa with regard to project readiness?

Response, Mr Phumzile Tshelane:

A possible stumbling block to project readiness in South Africa could be a bottleneck in terms of the regulatory aspects of the project. From the perspective of industry, challenges and bottlenecks may be experienced around localisation because of the problems with qualification of suppliers.

David Serfontein, North-West University:

How many people have died and are

expected to die as a result of the Fukushima accident? One might assume that 800 people would die as a result of Fukushima over a 40-year period, or 20 people would die from cancer each year. How would this number of deaths from nuclear compare to deaths from other sources of energy, such as coal? It is possible that too much attention is paid to nuclear accidents in relation to other accidents?

Response, Prof Robert Guillaumont:

It is difficult and may be not significant to compare the number of deaths resulting from each of the sources of energy or types of energy generation. It is better to compare, in my opinion, the consequences of accidents in terms of social impact. The social consequences of nuclear accidents with radioactive releases are very important. It is crucial that the containment of melted fuel be improved in the next generation nuclear reactors.

Ms Harrington:

I agree that there has to be a more concerted effort on new reactor types. We have been working with Russia for some years on the high-temperature gas-cooled reactor, but the fundamental problem has been that despite feasibility studies and bringing our scientific communities together, at some point industry should support a specific design and join with the government to develop the design. How do you facilitate that linkage between government efforts to support the R&D and the partnership with industry?

Response, Prof Adam:

One of the challenges is to recoup the investment on the Generation III reac-

tors that exist. The big vendors are desperately trying to sell their current Generation III plants. Industry is not ready to begin the rollout of Generation IV reactors, even if there was a system to roll these out. What we see is the development of pilot plants in fast reactors and other systems, and when the time is right, Generation IV reactors will be rolled out. Government should intervene where there is market failure. It is also necessary to understand that the process is very long. We are looking at multiples of human lifetimes in developing an energy strategy for the world that goes on for hundreds of years as opposed to tens of years. The systems can be developed, as long as there is a global pact between nations where this is accepted. This is not only a complex energy or physics problem, but also a complex international political problem to generate the required environment.

Response, Prof Guillaumont:

Possibly the next step in nuclear energy could be the operation of fast reactors cooled with sodium. This would bring a drastic change in nuclear energy. The challenges is to find a new core for nuclear reactors that would be passive and to set up a new industrial nuclear fuel cycle closed on plutonium multi-recycling, which is a difficult issue for many countries. There is research on this issue in France.

John Ledger, UJ:

Much is said about the carbon footprint, but it appears that South Africa does not have enough coal to make carbon. A new paper by David Routledge in the *International Journal of Coal Geology* predicts a 90 per cent depletion of lo-

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cal coal reserves within the next 60 years. It is evident that nuclear is an alternative energy resource.

Response, Prof Adam:

I agree that it is not only a uranium scarcity issue but also a coal scarcity issue. The question is whether we will have burnt too much by the time we run out of coal. This long-term resources issue could cause some of the investments in carbon sequestration to become obsolete. There is nothing on the horizon to address this.

Unknown person:

Eskom is supposed to prepare the stakeholder requirement specification (SRS), but how can Eskom act on behalf of other stakeholders?

Response, Prof Piet Stoker:

Eskom is ultimately responsible for the safety of any nuclear plant to be constructed in South Africa. As part of this responsibility, Eskom must assume the challenge of ensuring that the system is safe on behalf of all stakeholders. If Eskom is to follow a systems engineering approach, it should consult stakeholders and be aware of their interests and needs, ensure that these are included in the SRS at the highest level, as well as ensure that the needs are fully met.

John Ledger, UJ:

One of the stakeholders, the anti-nuclear movement in South Africa, does not abide by the rulebook and does not heed the referee. This movement has grown stronger with the arrival of Greenpeace in South Africa. How would the systems

engineering approach deal with the anti-nuclear movement and the possibility of the nuclear industry being taken to the Constitutional Court?

Response, Prof Stoker:

Transparency and openness are essential. The facts must be made available to all.

Response, David Serfontein, North-West University:

Legislation passed by the South African Parliament can be challenged based on the Constitution of this country. It would be reasonable to take the matter to the Constitutional Court.

Prof Adam:

We already have the World Nuclear Association (WNA), which is a fairly representative body, with representation generally at CEO level. Would you see that the WNA would play a role in the forum you suggest, or would you see an entirely different body being created?

Response, Prof Roger Cashmore:

The WNA is 'lobbying' for the nuclear industry. I chose the World Association of National Operators (WANO), because it has a clear responsibility for ensuring that there is a very high standard in operations of nuclear facilities, and the World Institute of Nuclear Security (WINS) because this is an upcoming, important body in nuclear security. I am sure there is cross-membership between WNA, WANO and WINS. It is essential to have a body that conducts serious independent peer review and publishes the results, ensuring implementation of the recommenda-

tions of the peer reviews. They will give the industry, the countries and the public confidence that nuclear facilities are being well operated.

David Nicolls, Eskom:

You mentioned the prospect of international peer reviews for nuclear security. This implies that a foreign body reviews your security plan. I am a little concerned that this would be challenging, as most countries see security as a state security issue. I doubt whether the US would accept a South African team, for example, reviewing the security of a US nuclear facility.

Response, Prof Cashmore:

This is a civilian mechanism. It is in all our interests to make sure that nuclear facilities are secure. South Africans may be a lot smarter at picking up nasty things that could happen to a reactor and it would be good, for example, if a South African team were to review US nuclear facilities.

Unknown person:

Have you contemplated private owner-

ship of reactors? Much has been said about government-owned facilities, but there is a move towards smaller reactors owned by large mining companies. How would the potential private ownership of reactors come into the security exercise?

Response, Prof Cashmore:

This is an interesting question. Small reactors will be developed in the future. All reactors in Britain are in private ownership. A new wave of reactors to be built in Britain will be built by commercial activities, without government sponsorship. Business will grow in terms of the small modular reactors, and these will be owned by private companies. They take delivery of the whole system, and contract waste companies to remove the spent fuel. This will become the standard commercial approach to energy production. This could be challenging, as it implies international trade and disposal activities. There will not be a problem with the ownership of the reactors, because the owners do not have an influence over how the reactors work. The reactors will merely be commercially supplied power sources.

Summary and Way Forward

Prof Rob Adam, Necsa

Prof Crewe informed delegates that the idea of holding this symposium had begun with the ASSAf commentary on the IRP 2010 requested by the Deputy Minister of Science and Technology. The idea developed during the meeting of the G8+5 Academies of Science attended by Prof Crewe, at which international participation in this symposium was promised, ensuring that the event would be distinct from other conferences on similar topics in South Africa. The international and local inputs to this symposium were very refreshing, original and decisive in conveying specific and relevant points.

Ms Harrington spoke about disarmament and global threat-reduction in the context of a growing nuclear power industry and focused on a low carbon future, mentioning various supporting frameworks such as International Atomic Energy Agency (IAEA) Peaceful Uses Initiative and the range of IAEA instruments. The role of the NNSA is to build partnerships and develop nuclear infrastructures. Ms Harrington maintained that South Africa was a nuclear security leader, based on the conversion of the South African Fundamental Atomic Research Installation research reactor to low-enriched uranium, from which radioisotopes were produced for commercial purposes. The new focus of the National Nuclear Security Administration in South Africa was on nuclear forensics, uranium characterisation and analysis. South African technical expertise

could be used to build regional capacity in this regard.

Mr Tshelane, of the Nuclear Industry Association of South Africa, explained that regulatory, finance, localisation, schedules, skills and public acceptance were the main risks related to nuclear energy. He approached risks from the standpoint of industry, where the project risk was of key importance. He spoke about project risks and how to avoid them, particularly in terms of the government's role in reducing the financial risk related to nuclear energy.

Dr Nariai, of the Science Council of Japan, described the causes and sequences of events at Fukushima, explaining that 78 000 people had been evacuated and that the radiation levels had fallen to 1.7 mSv/year at the site boundary. The evaluation of the robustness of plants in facing external events, seismic safety and severe accidents, as well as the comprehensive investigation of the fundamental cause, was explained. It was interesting that one of the possible risks of the Fukushima Daiichi plants was that the installation by Westinghouse and General Electric had been a turnkey installation, and there had been minimal research and development (R&D) depth of understanding of the plants that were installed. It was important to feed new knowledge back into the operation of the old plants, which required cooperation among various fields. In Dr Nariai's view, Japanese high-tech com-

panies came to the rescue in dealing with the accident at Fukushima, and this technical resilience of Japan made disaster-recovery possible.

Prof Guillaumont, of the French *Académie Des Sciences*, gave an excellent description of current global regulatory systems, explaining which were national and which were international. He recommended that research on current reactors, disaster occurrence probabilities, radiology, and accident remediation should be boosted and in particular, life extension should be examined. Innovative research, including research into new materials, cladding, fuels, remote control and measurements, should also be enhanced.

Prof Adam, of the South African Nuclear Energy Corporation, focused on the past, present and future scope of nuclear power, particularly in terms of fuel resources, public engagement and new technology development.

Prof Stoker, of the North-West University, presented a system's approach to nuclear energy safety. He described the IAEA's role of providing guidelines rather than regulations and explained the 'V' model for baseline management, stating that validation could only be done after the start of operation. He recommended that safety should be baselined and formally contracted throughout the contracting chain, and that the Inter-organisational Nuclear Knowledge Management System should be applied in the South African new nuclear build, which would involve a range of South African organisations currently operating in the nuclear sphere.

Adv Mkhize, of the National Nuclear Regulator, explained the role of regulatory authorities in future nuclear energy safety development, claiming that a clean record tended to be destroyed by a single lapse. He explained the various roles of a regulator:

- Promotional: based on organisations' values and behaviours.
- Corrective: providing guidance and support.
- Adjudicative: providing decisive intervention in the interests of safety.

He also described the global safety regime and its range of conventions, the safety reassessment and post-Fukushima stress testing that was being undertaken in all reactors around the world.

Dr Tsela, of Mzansi Energy Solutions and Innovations, masqueraded as the common man, assuring delegates that the public could no longer be ignored. He looked into the public acceptance of nuclear over the past ten years and asserted that Fukushima had not had a major impact on public opinion concerning nuclear power. The democratic legitimacy, ease of decision-making, and making the right choice to demystify nuclear, were other matters referred to in his presentation. It was necessary to:

- understand what the big public idea of nuclear was based on in order to supersede that idea, and focus on the benefits of nuclear energy rather than explaining its technicalities;
- engage with concepts that were in the consumer space and accept that the public was indeed rational.

Prof Cashmore, of the UK Royal Society, presented his talk only hours after the launch of the report, *Responsible Stewardship of a Nuclear Renaissance: Best Practice for Non-Proliferation*. He explained various key points of the report:

- Global governance that does not reflect the international reality of the nuclear industry.
- Recommendations that the Chief Executive Officer of the World Nuclear Forum should engage with governments.
- There was no time for complacency, as demonstrated by the attention to nuclear safety post-Fukushima, and avoiding complacency was vital to maintaining confidence in the nuclear renaissance.
- An integrated approach to safety and security, risk assessment and management should feature more prominently at all levels of decision-making, from the design and regulation, to corporate governance of nuclear organisations.
- The ability to safeguard nuclear energy remained an R&D priority.
- The dual risk of nuclear materials and technology being used in several military applications could not be eliminated.
- Strategic planning, from cradle-to-grave, is essential.
- The management of spent fuel and radioactive waste should no longer be an afterthought, and the entire fuel cycle would have to be considered.



Concluding Remarks and Vote of Thanks

Prof Roseanne Diab, Executive Officer, ASSAf

Prof Diab thanked the international guests in particular for their participation, as well as the organisations that had assisted with the delegates' travel, making specific mention of the French and Japanese Embassies in South Africa. The local speakers and the audience were thanked for their contributions to the interesting and engaging discussions. The staff members of the Academy were commended on the efficient organisation of the symposium.

Appendices

Appendix 1 - Symposium Programme



“Nuclear Energy Safety ” Symposium

Thursday, 13 October 2011

08:45 – 16:30

Innovation Hub, Pretoria

Agenda

| | | |
|---|--|---|
| 08:45 – 09:15 | Registration | |
| Chair: Prof Robin Crewe President, ASSAf | | |
| Time | Topic | Speaker |
| 09:15 – 09:20 | Welcome and purpose | Prof Robin Crewe <i>President, ASSAf</i> |
| 09:20 – 09:50 | Keynote address | Honourable Minister of Energy, Ms Dipuo Peters |
| 09:50 – 10:20 | Disarmament and global threat reduction in the context of a growing nuclear power industry | Ms Anne Harrington <i>US Department of Energy Office of Science</i> |
| 10:20 – 10:35 | Discussion | |
| 10:35 – 10:55 | Nuclear energy – understanding the risks | Mr Phumzile Tshelane <i>Nuclear Industry Association of South Africa (NIASA)</i> |
| 10:55 – 11:10 | Discussion | |
| 11:10 – 11:30 | Tea | |
| Chair: Prof Himla Soodyall ASSAf | | |
| 11:30 – 12:00 | Lessons Learned – Fukushima, Japan | Dr Hideki Nariai <i>Science Council of Japan</i> |
| 12:00 – 12:15 | Discussion | |
| 12:15 – 12:45 | Challenges and opportunities for enhancing the safety standards in the nuclear industry | Prof Robert Guillaumont <i>Académie des Sciences, Institut de France</i> |

| | | |
|-------------------------------|---|--|
| 12:45 – 13:00 | Discussion | |
| 13:00 – 13:20 | Challenges and opportunities for enhancing the development of safer nuclear energy technologies | Prof Rob Adam <i>Necsa</i> |
| 13:20 – 13:30 | Discussion | |
| 13:30 – 14:15 | Lunch | |
| Chair: Dr Van Zyl de Villiers | | |
| 14:15 – 14:35 | Nuclear Energy Safety: A Systems Approach | Prof Piet Stoker <i>North-West University</i> |
| 14:35 – 14:45 | Discussion | |
| 14:45 – 15:05 | The role of regulatory authorities in future nuclear energy safety development | Advocate Boyce Mkhize <i>National Nuclear Regulator</i> |
| 15:05 – 15:15 | Discussion | |
| 15:15 – 15:35 | Public engagement and perception of nuclear energy and associated risks | Dr Alex Tsela <i>Mzansi Energy Solutions</i> |
| 15:35 – 15:45 | Discussion | |
| 15:45 – 16:15 | Presentation on the Royal Society Report: 'Responsible stewardship of a nuclear renaissance: best practice for non-proliferation' | Prof Roger Cashmore (via videoconference) <i>UK Royal Society</i> |
| 16:15 – 16:30 | Discussion | |
| 16:15 – 16:25 | Summary and way forward | Prof Rob Adam |
| 16:25 – 16:30 | Concluding remarks and vote of thanks | Prof Roseanne Diab |

Appendix 2 - Biographies of Speakers



Professor Rob Adam is Chief Executive Officer of the South African Nuclear Energy Corporation (Necsa), South Africa's statutory nuclear technology organisation. He has held this position since 2006. He holds the title of Extraordinary Professor of Physics at both the University of Pretoria and the University of South Africa. Prof Adam also serves on the Council of the Academy of Science of South Africa, on the Board of Pebble-bed Modular Reactor (Pty) Ltd and chairs the Steering Committee for South Africa's bid to host the Square Kilometre Array Radio Telescope. Before joining NECSA, Adam was Director-General of the Department of Science and Technology, a position he held for seven years. In this capacity he was responsible for driving all major national science and technology initiatives of Government. Adam has held various academic positions in Europe and South Africa, and has published 25 refereed articles in theoretical physics.



Professor Roger Cashmore is the Principal of Brasenose College at Oxford University. He is a former Director of Research and Deputy Director-General of the European Organisation for Nuclear Research (CERN) where he was responsible for the experimental programme at the Large Hadron Collider (LHC). Currently his research interests focus on the LHC, using the Atlas Detector in which Oxford University is involved, and the search for dark matter in underground experiments. He is Chairman of the Ministry of Defence's Nuclear Research Advisory Council and member of the Royal Society's Advisory Committee on the Scientific Aspects of International Security (SAIS).



Professor Robert Guillaumont is an Emeritus Professor of Chemistry at the *Université Paris-Sud* in Orsay. His scientific background is around radiochemistry and actinides chemistry and his expertise is on the chemistry of nuclear fuel cycle (from uranium mining to waste management through reprocessing). He got his PhD from the Radium Institute (Paris). He has been appointed as Member or as the Head for many French and International Committees dealing with Nuclear Energy, Radwaste (Radioactive waste) Management (research and Safety) and the use of radionuclides. Today he belongs to the French Nuclear Safety Committee in charge of Radwastes and he is a member of the French Academy of Sciences.



Ms Anne Harrington was sworn in as Deputy Administrator for Defense Nuclear Nonproliferation for the National Nuclear Security Administration in October 2010. Previously, she was the Director of the US National Academy of Sciences Committee on International Security and Arms Control (CISAC), a position she held from March 2005 to October 2010. While at CISAC, she managed several key studies on a variety of nonproliferation, threat reduction and other nuclear security issues, including: *Global Security Engagement: A New Model for Cooperative Threat Reduction* (2009); *Future of the Nuclear Security Environment* in 2015 (2009); *Internationalisation of the Nuclear Fuel Cycle: Goals, Strategies, and Challenges* (2008, joint report with Russian Academy of Sciences). Harrington served for 15 years in the US Department of State, where she was Acting Director and Deputy Director of the Office of Proliferation Threat Reduction and a senior US government expert on nonproliferation and cooperative threat reduction. She has dedicated much of her government career to developing policy and implementing programmes aimed at preventing the proliferation of weapons of mass destruction (WMD) and missile expertise in Russia and Eurasia, and also launched similar efforts Iraq and Libya. Harrington has been author or co-author on a number of papers on the role of the scientific community in preventing proliferation of WMD expertise and approaches to countering biological threats.



Advocate Boyce Mkhize is currently the Chief Executive Officer of the National Nuclear Regulator (NNR). Boyce is a lawyer by training possessing B.Juris and LLB degrees from the University of Zululand and an admitted Advocate of the High Court of South Africa. Prior to him joining the NNR in 2010, he was the Registrar and Chief Executive Officer of the Health Professions Council of South Africa (HPCSA). While CEO of the HPCSA, Boyce also served as the Secretary-General of the Association for Medical Councils of Africa. He also served as Chief Legal Advisor and Company Secretary for the then Atomic Energy Corporation, now known as the South African Nuclear Energy Corporation (NECSA). Prior to this he had served in Government Departments in various capacities which included being Chief of Staff in the office of the Minister of Public Service and Administration and Deputy Director for Affirmative Action Policy and Transformation. Boyce also serves in Boards and Councils of a few public institutions and private companies in South Africa.



Dr Hideki Nariai is the former President of the Japan Nuclear Energy Safety Organisation (2003 – 2009), following a brief period as the President of the Atomic Energy Society of Japan. He graduated from the University of Tokyo, where he obtained a doctorate in Engineering. He then joined the Ship Research Institute as a research engineer for the Nuclear Ship Division from 1967 - 1980. Nariai spent a year at the Massachusetts Institute of Technology as a visiting Engineer at the Department of Mechanical Engineering. He was then appointed as Associate Professor, Professor and thereafter Emeritus Professor at the University of Tsukuba, Japan. Nariai's key interest areas are nuclear thermal hydraulics and nuclear safety. He is a member of the Science Council of Japan.



Professor Piet Stoker joined the North-West University in 2005 as Head of the Centre for Research and Continued Engineering Development (Vaal). He has since built up a research group comprising 15 PhD and 4 Master students working in the area of: "nuclear policy and business studies". Prior to this Stoker worked in the Mining, Utilities and Arms Development industries as consultant. He was CEO of MEGKON (Pty) Ltd, a technology development company, for a period of 20 years. During this time the company grew to an international enterprise, and won the Technology Top 100 category award five times. He served on the South African Council of Professional Engineers (the predecessor of Engineering Council of South Africa from 1983 to 1988 and he has been a registered Professional Engineer since 1978.



Dr Alex Tsela is the Chief Executive Officer of Mzanzi Energy Solutions and Innovations. He has held several strategic roles in the past. Amongst others, Dr Tsela was the Chief Executive Officer of the Pebble Bed Modular Reactor Company, the General Manager of the Nuclear Compliance Assurance, and on the Board of Directors in the Nuclear Industry Association of South Africa (NIASA). He was interim CEO, after being the Head of Regulatory Strategy and a Radiation Protection Specialist, at the National Nuclear Regulator of South Africa. His focus areas were on leading research and development, safety standards and regulations, international liaison. Prior to this he was a lecturer in physics at the University of the Witwatersrand and University of Swaziland. He holds a PhD in Nuclear Physics from the University of the Witwatersrand, MSc Nuclear physics from the University of Sussex and an MBA from the University of Pretoria.



Mr Phumzile Tshelane is the Vice-President of the Nuclear Industry Association of South Africa (NIASA). He is currently employed full time by Eskom, where he participates in the development of execution plans for the Eskom nuclear build programme. He is also the non-executive Director at the South African Nuclear Energy Corporation (Necsa). In the past 20 years, he has served in several national and international organisations and he has proven excellence as a technology strategist.

Appendix 3 - Symposium Attendees

| Name | Surname | Affiliation |
|----------|-------------|--|
| Rob | Adam | Necsa |
| Kerry | Armstrong | UJ |
| Frik | Beeslaar | Necsa |
| Pat | Berjak | UKZN |
| Kerry | Bethel | Koeberg |
| Johann | Breytenbach | Koeberg |
| Keith | Campbell | Creamer Media |
| Louise | Cawood | Necsa |
| Morakeng | Chiloane | ASSAf |
| Cameron | Coates | Oak Ridge National Laboratory |
| Robin | Crewe | ASSAf |
| Van Zyl | De Villiers | Necsa |
| Geert | De Vries | Independent Consultant |
| Roseanne | Diab | ASSAf |
| Grace | Djan | University of Potchefstroom |
| Wilhelm | Du Plessis | North-West University |
| Heather | Erasmus | Write Connection (Scribe) |
| Linda | Fick | ASSAf |
| Wieland | Gevers | ASSAf - UCT |
| Mike | Gillard | Koeberg |
| Robert | Guillaumont | <i>Academie Des Sciences, Institut de France</i> |
| Nicholas | Hardman | UJ |
| Anne | Harrington | United States DoE |
| Kelvin | Kemm | Stratek |
| Fionah | Khathi | UJ |
| Eva | Khoza | University of Pretoria |
| Charles | Kros | Necsa |
| Tjaart | Le Roux | Vodacom |
| John | Ledger | University of Johannesburg |
| Daan | Louw | Necsa |
| Sunil | Maharaj | ASSAf |
| Pogisho | Maine | Department of Energy |
| Lebo | Makgae | ASSAf |

| | | |
|-------------|-------------|------------------------------------|
| Lerato | Makgae | Eskom |
| Mosidi | Makgae | Eskom |
| Reuben | Makgae | DoE |
| Mpho | Makgale | Department of Energy |
| Johan | Malherbe | University of Pretoria |
| Katse | Maphoto | Department of Energy |
| Ramatsemela | Masango | Necsa |
| Boyce | Mkhize | National Nuclear Regulator |
| Mohau | Moja | ASSAf |
| Zarina | Moolla | ASSAf |
| Thuthukile | Mosia | Technology Innovation Agency (TIA) |
| Tshinyadzo | Mphephu | Portfolio Committee on Energy |
| Zuki | Mpiyakhe | ASSAf |
| Mumy | Mthembu | Eskom |
| Thato | Mthimkhulu | Necsa |
| Vishnu | Naicker | North-West University |
| Hideki | Nariai | Science Council of Japan |
| Umesh | Natha | Necsa |
| Sabelo | Ndawule | Eskom |
| Zweli | Ndayi | ASSAf |
| Patrick | Nemushungwa | ASSAf |
| David | Nicholls | Eskom |
| Samantha | Nkomombini | Eskom |
| Larry | Obi | Walter Sisulu University |
| Toshiro | Ozawa | Ambassador of Japan |
| Iqbal | Parker | ASSAf |
| Gopolang | Pete | DoE |
| Mmadisime | Phetoe | Necsa |
| Thabo | Radebe | ASSAf |
| Ruby | Ramatsui | Eskom |
| Niyum | Rampersadh | NTP Radioisotopes |
| Charles | Randolph | US Embassy |
| Mosa | Rasweswe | Necsa |
| Crystal | Robinson | Koeberg |
| Pieter | Rousseau | North-West University |
| Mike | Sathekge | University of Pretoria |

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| | | |
|------------|--------------|---|
| Patricia | Scholtz | ASSAf |
| David | Serfontein | North-West University |
| Joseph | Shayi | Necsa |
| Rhulani | Shingwenyana | Exxaro |
| Himla | Soodyall | ASSAf |
| Rod | Speedy | Eskom |
| Piet | Stoker | North-West University |
| Masa | Sugano | Embassy of Japan |
| Nthabiseng | Taole | ASSAf |
| Ryan | Taugher | US Department of State |
| Riccardo | Temmers | Koeberg |
| Josephine | Thauge | Eskom |
| Sishuba | Thulisile | University of Johannesburg |
| Ntsoaki | Tlape | Nuclear Fuel Department |
| Sadika | Touffie | Eskom |
| Alex | Tsela | Mzansi Energy Solutions and Innovations |
| Phumzile | Tshelane | NIASA |
| Victor | Tshivhase | North-West University |
| Henriette | Van Graan | Necsa |
| Louise | Van Heerden | ASSAf |
| Frikkie | Van Niekerk | North-West University |
| Fanie | Van Rooyen | Beeld |
| Susan | Veldsman | ASSAf |
| Wolfgang | Veldsman | Jet Press Solutions Pty Ltd |
| Hennie | Venter | Necsa Licensing Department |
| Zebulon | Vilakazi | TIabs |
| Henriëtte | Wagener | ASSAf |
| Lawandiso | Zamxaka | Eskom |

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<http://research.assaf.org.za/>

A. Academy of Science of South Africa (ASSAf) Publications

B. ASSAf Workshop Proceedings and Other Reports

2012

Nuclear Energy Safety Symposium. Proceedings Report

Academy of Science of South Africa (ASSAf)

Academy of Science of South Africa

Academy of Science of South Africa (ASSAf), (2012). Nuclear Energy Safety Symposium.

Proceedings Report. [Online] Available at: DOI <http://dx.doi.org/10.17159/assaf/0012>

<http://hdl.handle.net/20.500.11911/42>

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